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RIVERSIDE TEXTBOOKS IN EDUCATION

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EXPERIMENTAL EDUCATION

Laboratory Manual and Typical Results

BY

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EDITOR'S INTRODUCTION

THE experimental investigation of educational problems had its origin, in large measure, among the workers in psychological laboratories. The subject-matter of the problems is chiefly psychological in nature. Many of the methods which have been developed in the psychological laboratories are applicable to the study of the problems of education, and some of the problems in psychology, particularly those of learning and memory, have direct bearing upon education.

During recent years experimental education has experienced a very rapid growth, and there have been extensive developments in certain specialized directions. The fields in which this work has been largely done are the investigation of the learning process which characterizes progress in the subjects of study in school, the accurate measurement of attainment in these school subjects, and the determination of individual ability through tests of mental maturity, intelligence, and individual differences. These problems, while of the same general nature as those studied in the psychological laboratories, are in the main untouched in the work of these laboratories and in the manuals which have been prepared for the guidance of their

work. Under these conditions the formulation of courses of experiments for students in education, which shall meet the special demands of this particular field of investigation, is highly desirable, since the organization of manuals to serve as guides in such courses has not kept pace with the research which has been carried on. This is the natural result of the newness of the field, of its lack of organization, and of the variable quality of the work which has been done in it.

The present volume of this series of textbooks is an attempt, by a psychologist who has been engaged in much of this newer type of educational investigation, to make a workable organization of this new field in applied psychology, to sift the valuable phases of the work from those which are ephemeral, and to formulate a series of experiments which shall introduce the student to the more important problems of experimental education. As such it is hoped that it may prove of much use to students of such problems as are here included.

ELLWOOD P. CUBBERLEY

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EXPERIMENTAL EDUCATION

CHAPTER I

INTRODUCTION

WITHIN the past ten years there has been very marked activity in the scientific study of the psychological problems involved in education. This activity is evidenced by the large number of papers reporting experimental studies, read before meetings of educational and psychological associations, and by the stream of articles dealing with experimental education appearing in educational and psychological periodicals. This investigation of educational problems by the general methods developed in the psychological laboratory was instituted and promoted in the first place by professional psychologists, and originally dealt with problems of general psychological analysis. In the course of its development, however, both the aim and the content of this study have shifted, and it has become necessary to reformulate them in order to meet the demands of students who are interested in the psychological aspects of education.

The earlier applications of psychology to education dealt primarily with the development of general psychological principles, and secondarily with their application. The first consequence of this emphasis on the

theoretical side was that, since there were no clear standards as to what was of most importance from the practical point of view, much time was spent on the elaboration of principles which were relatively unimportant for education. The second consequence was that, since the basis of classification was the psychological system, the facts or principles which applied to any particular problem, such as reading or writing, were scattered through various parts of a course instead of being focused on the practical problem itself.

The course which is here presented accordingly proceeds, for the most part, from the opposite starting-point. Instead of developing the general psychological principles and laws, and then making incidental application, it attacks directly the practical problems and attempts to throw light upon them by an analysis of the psychological principles which are involved in them. This means that the selection of problems is based directly on their practical importance, and that the arrangement is such as to bring together the facts which serve to illuminate some one practical problem.

An exception to this general rule that the experiments deal with specific educational problems rather than with general psychological principles, appears in the early experiments, which deal with learning and memorizing. This exception is justified by the very wide and evident application which these principles have in education. The purpose of the experiments in this first section is to cause the student to make an

analysis of his own learning process, and to compare his learning process with that of others, to the end that he may know what the conditions of efficient learning are, and how the learning of others may be most effectively directed. For this reason the conditions of learning are experimentally varied in such a manner that the effect of different conditions may be compared. A variety of typical forms of learning are employed, including rote and sense memorizing.

In the next group of experiments the student is led to examine forms of learning which are represented in the fundamental subjects of the school curriculum. We are here dealing with special problems which have a still more direct application to school procedure than does the analysis of the learning process in general. Besides the analysis of the mental process involved in the learning of the school subjects, it is of great value to the administration of education to be able to measure the attainment of pupils in the various branches by means of tests which render the results comparable to general standards. Accordingly, two examples of such test methods are included in the experiments on the school subjects.

Finally, for the proper direction of the pupil's learning process, it is necessary that we shall have information regarding his intellectual equipment for the tasks which are required of him. The detection of defects in the avenues by which experience is acquired necessitates the discovery and correction of, or allowance for,

sensory defects. A general knowledge of the methods of testing for sensory defects is desirable. The methods of testing other types of ability can be illustrated only roughly, and the qualification must always be kept in mind that the results with adults cannot be applied directly to children. Various test methods can be illustrated, however, so as to give an acquaintance with the types of tests which give an insight into important individual and age variations. Opportunity may also be given to become familiar with the methods of studying the interrelation of mental traits and with some of the typical results of such a study.

In addition to an appreciation of the facts of learning established by the experiments, the course should stimulate the student to make a study of the process of experimentation itself, and to form a notion of the chief characteristics of a valid experimental method. The main features of the experimental method have been frequently described, and may be briefly illustrated here as an introduction to the experiments themselves.

The aim of scientific investigation may be said to be to study the uniformities in the facts or processes which are the subjects of study. This usually resolves itself into a study of the relationship of one series of events to another as to cause and effect. Thus, the study of the events of the physical world has led to the discoveries of certain uniformities or laws, such as the law of gravitation, the laws of light and sound propagation, and the law of evolution. Now, the discovery

of such uniformities merely by the observation of the events as they occur spontaneously, is very difficult, since a particular event may never occur twice with precisely the same surrounding conditions, or two events between which the relationship is to be discovered may always occur intermingled with a variety of others. Thus, it was difficult to determine purely by observation whether or not the bite of a mosquito is related to yellow fever as cause to effect, because there were associated with this condition a variety of others — such as contact with those who were afflicted with the disease — to complicate the relationship. Under these circumstances the experimental method was resorted to in order to simplify the conditions by artificially producing the events which were to be studied, in isolation from others. That is, an investigator first exposed himself to contact with a yellow-fever patient while carefully protecting himself from the bite of the mosquito; and then exposed himself to the mosquito bite while remaining isolated from infected patients. The experiment proved to be crucial and conclusive by the immunity of the investigator in the first case and his infection in the second.

Sometimes the aim of an experiment is not so specific as this. Instead of seeking to determine which of two alternative explanations is correct, the experimenter may attempt to make a more general analysis or survey of certain phenomena, for the sake of discovering any laws which may be revealed, and of hitting upon prob-

lems which may be attacked in a more specific manner afterwards. Such an experiment is illustrated in the well-known Bryan and Harter experiment in learning the telegraphic language. In the first survey experiment the authors discovered the existence of a plateau or long level place in the curve of progress. Their later experiment was for the purpose of discovering the cause of this phenomenon by further analysis of the learning curve into several curves, representing progress in receiving isolated letters, disconnected words, and connected discourse.

Whether an experiment is of the crucial or of the general-survey type, it has certain characteristics which must be adhered to if it is to give results which are reliable. First, all the conditions which might affect the result in any degree must be controlled, as far as possible; or, if they cannot be controlled completely, they must be accurately measured or observed and recorded. The simplest method, and the one which is pursued as far as possible, is to keep all the conditions constant except one, and then to vary one condition by a certain known amount, and measure the result. Thus, we may measure the effect of practice by giving a person a certain specified amount of practice in a particular activity, and by noting the change in his ability without introducing or allowing a change in any other condition which would affect the result. If the person were in better health in one part of the period than in another, or if he also practiced in some related

field which affected his progress in the one under investigation, these factors would have to be taken into account.

It is frequently impossible or very difficult to study one factor in isolation, and in such cases it may be necessary to make check experiments. J. E. W. Wallin made an investigation [1] of the effect of correcting defects of the teeth and instituting correct habits of care of the mouth, in the case of school children, which illustrates this point. A group of children were tested mentally before, during, and after the correction of mouth defects and the institution of habits of hygiene, which tests continued for several months, and a large improvement was found. But other factors than oral hygiene affected the results; namely, general increase in maturity, school work, and the practice with the tests themselves. Wallin himself recognized this fact, and wrote that it had been his plan to give check tests to other children who had not received the special treatment. This would have made it possible to discount the other factors. This principle of the check test has a very wide application, and will be illustrated in several of the experiments of this course.

Whatever the special character of an experiment, the procedure must be objective and verifiable. The possibility of verification by the repetition of the experiment by another rests upon the objectivity of the

[1] J. E. W. Wallin, "Experimental Oral Euthenics"; in *Dental Cosmos*, April and May, 1912.

procedure. It therefore is necessary to be clear as to the meaning of objectivity. Objectivity is contrasted with unsupported opinion. In a scientific experiment it requires that the conditions be so controlled and reported that they may be duplicated. It means further that the results be carefully measured and presented, or, when measurement is not possible, that they be fully and accurately described. It means finally that the conclusions which are drawn shall rest upon the results which are presented, so that another person may check them up by reference to the results on which they are based.

These are, in brief outline, the chief requirements of a valid scientific experiment. A word should be said about the presentation of results. When a number of experiments are made with the same subject, or when a number of subjects are experimented upon, it becomes necessary to employ some method of formulating the mass of results so as to show their trend. Frequently the significance of the results is dependent upon the skill with which this formulation is made. Two general methods of formulation may be distinguished; the tabular presentation or statistical formulation of numerical data, and the graphic presentation of data. Both of these methods will be illustrated in the presentation of typical results of the following experiments. A concise account of the chief methods may be found in G. M. Whipple's *Manual of Mental and Physical Tests*, vol. I, chap. 3.

The chief conditions for a valid experiment may be summed up in a *set of rules:* —

1. So far as possible a single factor should be isolated for study. When this cannot be done, check experiments should be made.
2. All the conditions of the experiment should be made quantitatively as precise as possible. This includes the regulation of the stimulus as to the amount, duration, and interval, and the measurement of response. Where required, it also involves the correct statistical formulation of results. It should go without saying, but unfortunately does not, that all calculations must be accurate. Every calculation should be checked.
3. In some cases a qualitative interpretation gives the results more significantly than a quantitative formulation of results.
4. The analysis or interpretation of results is extremely important, particularly in a survey experiment.
5. An immediate record should be made of everything which occurs, as introspections, and all records should be completely identified.
6. An objective, impartial attitude toward the results is essential.
7. The problems which are raised by the experiment should be noted as well as the solutions which are obtained, and, if possible, modifications of the experiment should be set up to attack them.

8. The conclusions should be generalized only so far as the results justify.

The value of an experiment to others depends on the way it is reported, as well as on the character of the experiment. To make the report complete it should include: —

1. A brief but clear statement of the problem.
2. An account of previous investigations leading up to the present one.
3. A more detailed statement of the problem and method of the experiment, including a sketch of the apparatus.
4. A presentation by tables, graphic figures, and explanatory statements of the detailed and summary results.
5. An interpretative discussion of the results.
6. A discriminating statement of conclusions.
7. A bibliography of the references used in the report.

In the set experiments of this course Nos. 2 and 7 may be omitted, but they are necessary in an original investigation.

Note to the instructor

Most of the experiments which are here outlined are intended to be performed by pairs of students working together. Each student should work both as experimenter and as subject.

Each student is expected to turn in a full written

report, which should include the numerical or other data which were obtained by himself as subject and a complete analysis and interpretation of the results. After all the individual reports are in for an experiment, some member of the class should combine the data from all of these into a group report. This group report should be presented at a class meeting, and thoroughly discussed. This presentation and discussion of the group results is the most valuable phase of the whole work. It makes it possible to discover the general results as they emerge from the variety of the individual results, and also makes each experiment a study of individual differences. Furthermore, it gives excellent opportunity to comment on violations of correct experimental procedure and to bring home the principles of valid experimentation.

NOTE. — The apparatus used in this course can be obtained from the psychology shop of the University of Chicago by writing to the author, or from C. H. Stoelting & Co., Chicago. Prices will be quoted on application.

CHAPTER II

ANALYSIS OF VARIOUS TYPES OF THE LEARNING PROCESS

One of the most fruitful fields of experimentation in education is the analysis of the learning process. Many experiments in this field have been made, and a variety of types of learning have been studied.

The types of learning which have been the subjects of investigation may be classified, roughly, into four groups: —

A. The development of a motor coördination.
B. The development of adequate perception.
C. The formation of associations between perceptual or ideational elements.
D. The analysis of a situation.

Such a classification as this is of value because it distinguishes between processes which differ from the descriptive point of view, as well as in the methods which are best suited to hasten progress in the several kinds of learning. It must not be inferred, however, that the same task may not include more than one kind of learning, or that similarities between the various kinds of learning cannot be found.

Experiment No. 1

SENSORI-MOTOR LEARNING

Problem. The first experiment is for the purpose of illustrating the development of a motor coördination. The development of motor coördination in its simplest terms consists in the adjustment of a movement to a stimulus, or, more particularly, in the development of the ability to make movements which shall meet certain conditions presented in perceptual form. Physiologically, motor learning consists in the formation of appropriate nervous connections, or paths of discharge, between certain sensory centers and certain motor centers. This is the matter reduced to simplest terms. The process of such development is illustrated by J. H. Bair's experiment in learning to move the ears. There being no instinctive connection between the sensations which accompany ear movements and the movements themselves, this connection has to be formed through practice. A more complex type of learning consists in adapting a series of movements to a complex stimulus or to a changing stimulus. Swift's ball-tossing experiment, and the experiment included in this course, are relatively simple examples of this type. The matter becomes more complex when it becomes necessary to organize the perceptual or motor elements, as in Bryan and Harter's experiment with telegraphy or Swift's or Book's experiments in learning to use the typewriter.

Such experiments have a direct bearing upon education wherever it is concerned with the development of motor skill, as in handwriting, drawing, and the manual arts generally. The results of such experiments also have an indirect bearing on education by means of the discovery, through them, of general principles of

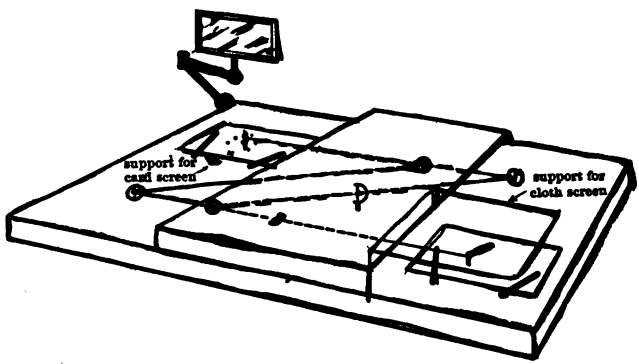


FIG. 1. DRAWING OF APPARATUS USED IN EXPERIMENT NO. 1, SHOWING THE GENERAL RELATIONS OF THE MECHANISM

the learning process — as, for example, the relation of effort to progress in learning.

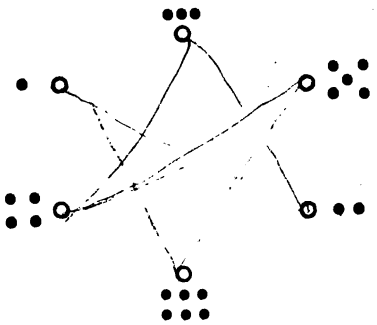
Material and method. The learning process in this experiment consists in adapting simple hand movements to the drawing of a series of lines to connect a group of dots, when the relation between the direction of the hand movements and of the movement of the pen which produces the lines is different from that to which one is accustomed. The modification in the relationship between the hand movements and the result-

ing pen movements is made by means of a mechanism, the study of which is left to the student. (See Fig. 1.) In addition to the modification produced by this mechanism, the *apparent* direction of the pen movement is changed, not by mechanical adjustments, but by the use of a mirror. By varying the position of the mirror, this apparent direction may be changed at will. For the study of progress in learning, let one person of each pair place the mirror parallel to the long side of the board which is farther from the subject. Let the second member of each pair place the mirror parallel to the left side of the base.

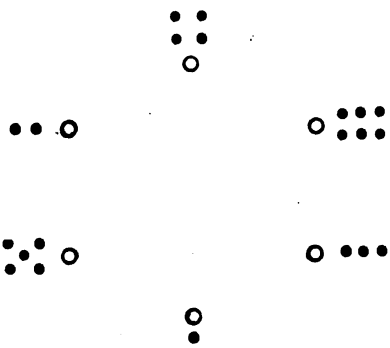
The apparatus should be placed so that the long side of the base is parallel to the edge of the table, and the handle in a convenient position to be manipulated by the right hand.

Stimulus card No. 1 is to be used in this experiment, and is to be placed with the margins parallel to the edges of the apparatus and with the X toward the subject. The stimulus cards are shown in the accompanying Figure 2.

To indicate the order in which the lines are to be drawn, small groups of dots are used, instead of figures, since the figures would have to be reversed in order to be read in a mirror. The lines are to be drawn from circle 1 to circle 2, then to circle 3, and so on; and the star should be finally completed by connecting circles 6 and 1. The aim of the subject should be to cause the pen to touch each dot in succession



Stimulus Card No. I.



Stimulus Card No. II.

FIG. 2. ARRANGEMENT OF CARDS USED IN EXPERIMENT NO. 1

as rapidly as possible, and the criterion of progress may be the reduction of the time taken to complete the whole figure.

Since the accuracy requirement is constant, namely, that each dot shall be touched in succession, the time taken serves as a convenient and sufficiently adequate measure of efficiency.

The experimenter should note the time of each trial with a stop-watch, and should attend to changing the cards, keeping the pen supplied with ink, etc.

Twenty-five tri-

als should be made with the card and mirror, as indicated above.

The subject should make note during the experiment of any introspections he may make regarding the means by which improvement is attained, the direction of his attention, etc.

In order to throw light upon the value and limitations of instruction in this type of learning, the following method should be employed: Let one student of each pair first go through the experiment without instruction or any special consideration of the methods of learning. Let him then develop, as best he can on the basis of his own experience and of his reading, the principles and rules of economical sensori-motor learning, and instruct his partner in these rules and principles. These instructions should be formulated in writing and included in the report. They should not be made too specific, but should be of such a kind that they could be applied to other tasks in learning which are of a similar nature. The second student may also obtain what light he can on the best method of procedure from an observation of his predecessor, and should give an account of his conclusions in his report. He should also discuss the question whether the instructions were of assistance to him. The general report should include a comparison of the records of the instructed and uninstructed learners.

Treatment of results. A curve of progress should be constructed by charting, on cross-section paper, the

time taken for the successive trials. Each trial may be represented by a unit on the horizontal axis, and the height of the curve above these successive unit distances may represent the length of time required for the succeeding trials. Thus a drop in the curve means decrease in the time required, or improvement.

An analysis of the practice curve should be made, so as to explain its general form and any fluctuations which may appear. In the analysis and interpretation of the curves, use should be made of the notes on introspections.

The numerical results which are the basis of the practice curves should be presented in the form of tables.

The general report upon this experiment should discuss, first, individual differences with reference to the rate of improvement, the amount of skill attained, the suddenness or gradualness of improvement; and, second, the general facts common to the individual results, as the part of the practice series at which the more rapid part of the improvement occurs, and the effect of intelligent instruction upon learning. A general summary should also be made of the individual analyses and interpretations. This should include a discussion of the difficulties which had to be overcome and the methods and devices which were employed in overcoming them.

Results of the experiment. Some of the most significant results of this experiment are derived from an

analysis by each subject of his experience in the learning, and from the interpretation of this experience so as to apply the conclusions to similar forms of learning, such as handwriting. In order to give opportunity for some originality in this analysis and interpretation, the discussion of these matters will not be entered upon here. The province of "instruction" in this type of learning, and the kind of instruction which is of most value, is directly related to the learning process.

Typical objective data on which the interpretative discussion just mentioned may be based are presented in Chart I. It is clear that there is some radical difference between the "instructed" and the "uninstructed" groups which is to be explained. The difference is not accidental, since this is a typical case. The question should be raised whether the verbal instructions in this case constituted the only factor which was different in the two groups. If the analysis of the situation should lead to the conclusion that there are other differences between the groups introduced by the conditions of the experiment than that of the presence or absence of verbal instructions, the importance of these other factors should be estimated. If there is opportunity to carry on other experiments the relative importance of instruction and of these other factors may be measured.

The median curves give a good basis for the discussion of the general form of the practice curve, and for an attempt to explain it. In this discussion it is well to

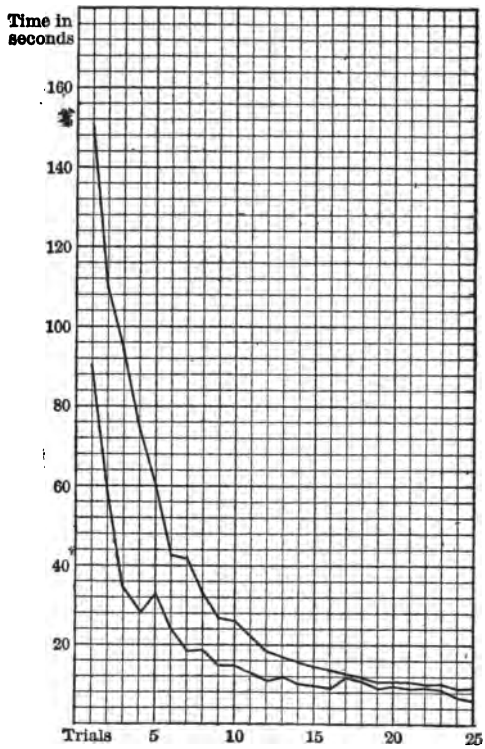


CHART I. CURVES OF PROGRESS IN MODIFIED MIRROR DRAWING BASED ON THE MEDIANS OF TWO GROUPS OF INDIVIDUALS

The upper line represents the "uninstructed" group (eleven individuals) and the lower line the "instructed" (nine individuals).

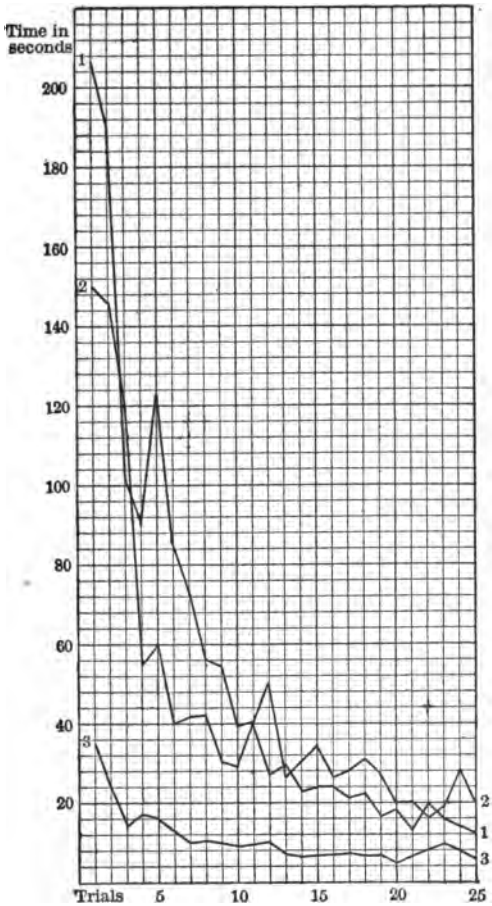


CHART II. CURVES OF PROGRESS OF THREE INDIVIDUALS IN MODIFIED MIRROR DRAWING

Showing individual differences in rapidity of the sensori-motor process and in rate of improvement. The fluctuations in an individual's practice curve are also brought out. It should be noted that the scale of this chart in respect to the representation of the time of the trials is reduced, making the height of the curves half that of the curves of Chart I.

compare the form of these curves with that of others, as, for example, those of Bryan and Harter's experiment, and the ball-tossing experiment of Swift.

The great individual differences which appear in such a form of learning as this are clearly illustrated in Chart II. These extremes are not at all unusual. Their significance and educational bearing may be discussed. The introspective notes should throw some light on the fluctuations which are to be observed in the individual curves.

A comparison of the records of those individuals who attempt to analyze the relationship of the hand movement to the pen movement, in order to guide their efforts by a comprehension of this relationship, indicates that, on the average, they take more time to learn than those who abandon such attempts and resort to random trial. In one group the average time spent by those who attempted analysis was forty-five seconds per trial, and by those who did not, thirty-one seconds.

Extension of the experiment. It would be worth while to know whether those who make a thorough analysis before starting are benefited thereby in their first set of trials, and also whether they do better when the conditions are modified, as in Experiment No. 4. To study this question a class may be divided into two equal groups. One group may then proceed according to the regular directions, and the other may remove the cover, study the levers, and work out by diagram

the relationship of the pen and the hand movements to the movements of the hand. This should be done without practicing making the movements with the hand.

A marked plateau does not usually appear in this particular form of learning so far as it is carried. The experiment may be extended by adding other trials to determine whether a plateau would then appear. A further extension may be made by trying the experiment with children of different ages. If opportunity offers, the correlation between ability in this task and in other forms of sensory motor learning might be found.

QUESTIONS AND TOPICS FOR DISCUSSION

These questions are intended to stimulate reflection upon the wider applications of the experiment.

1. What are the likenesses or differences between the problem confronting the subject in this experiment and the problem before the child in learning to write?
2. What is indicated by the experiment regarding the sphere of the trial and success method in learning? Of what value is the attempt to analyze the conditions of the problem?
3. *a*. What bearing does one's general attitude, as of confidence or the reverse, have upon progress?
   b. What bearing does physical condition have?
   c. What is the effect of special effort?
4. Does a knowledge of the laws of learning have any beneficial effect upon the control of the feelings and one's attitude toward them?
5. In what respect and to what extent is instruction of value in facilitating progress?
6. What bearing do individual differences have on the development and application of instructions?
7. Is the possibility of analysis greater or less in this experiment than in the child's sensori-motor learning?
8. What is the role of repetition in such learning as this?
9. How are trials made more correct — by a study of the movement or of the external result?
10. What place has the study of the movement?

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Experiment No. 2

PERCEPTUAL LEARNING

Problem. The second experiment deals with a type of learning in which the perceptual element is predominant. This element enters into many forms of learning which seem at first sight to be mainly motor in character. In handwriting, for example, the perception of form precedes its reproduction, and also is made more precise by the effort at reproduction. In typewriting the comprehension of the relation of the letter positions on the keyboard to the letters which compose a printed or imagined word is at first chiefly a matter of perception. Finally, it is now recognized that in drawing the perceptual element is of more importance than the motor element. The ability to arrange proportions and directions of lines in such a way that they will constitute the picture of an object is more a matter of seeing relationships in space properly than of skill in handling a pencil. Drawing a figure in which the elements present no technical difficulty is therefore an excellent means of testing the accuracy of perception and of tracing the development of perception.

Material and method. For this purpose a series of six figures may be used (and these are reproduced in the Appendix). The experimenter should be prepared with a watch having a second hand, and a series of

cards upon which the figures are drawn. The cards should be placed face down and arranged in order, with the first one on top. The subject should be provided with a number of sheets of paper the same size as the cards. After a ready signal, the experimenter should hold the first card in such a position that the subject may see it clearly for ten seconds. When the card is lowered, the subject should immediately draw what he can of the figure and then turn or fold the sheet over so as to conceal what he has drawn. The figure should then be presented again and drawn from memory. This procedure may be repeated until the subject is confident that he has mastered the figure. The experimenter should observe and note any actions on the part of the subject which give indication of the method by which he attacks the figure.

The comparison of instructed and uninstructed learning should be made in the same manner as in Experiment No. 1.

The person who serves as experimenter should avoid becoming familiar with the figures while his partner is drawing them.

Treatment of results. The experiment is not chiefly to measure efficiency or rate of learning, but to analyze and describe the mental process by means of which the learning proceeds. To this end it is essential that the subject make a careful note of the results by the most careful introspection he can make. He should have paper at hand upon which he can make brief notes as

the experiment proceeds, and which he can elaborate when it is finished. Further data regarding the stages in the development of a perception may be gathered from the drawings themselves. These are to be examined for the purpose of analyzing them qualitatively rather than of measuring them quantitatively. The drawings themselves, and a table giving the number of presentations for each figure, should be included in the report to serve as a basis of the general report.

After each student has worked up his own results, they may with advantage be compared with those found by the other members of the class in the general report. In this way individual differences in the method of attacking the figures may be discovered. The general report should also make a comparative study of such matters as the order in which the parts of the figure are learned, the number of gross errors made in different figures, or different sorts of lines, etc. The general report should also give an analysis of the learning process in this experiment and compare it with the report of the study by Judd and Cowling, and should compare the process in instructed and uninstructed learning.

Results of the experiment. The chief results of this experiment are to be found in the analysis of the process of perceptual learning, as suggested in the topics for discussion. The numerical data are here subordinate to the introspective account of the process and a

description of the mode of procedure, as far as such can be made from an examination of the drawings themselves. From such an examination it will appear, for example, that the scrutiny of such figures as these for the purpose of reproducing them proceeds, whether consciously or unconsciously, in accordance with certain previously formed habits. Thus it will be found that, with very few exceptions, the examination of the figures begins at the left. In general there is a large amount of active exploration of the figures rather than a passive reception of impressions. The bearing of past experience in influencing the manner in which the elements of the figure are organized, appears clearly in the manner in which groups of lines become intimately fused into an organic whole because they resemble some familiar form, and in the application of concepts or modes of interpretation such as line, angle, and number. Analysis and synthesis are both evident.

Complete tables would show individual differences in the number of trials taken and the number of errors made, but space need not be taken for them here.

The use of instructions for a part of the students in this experiment — in the manner in which they are used — serves rather to raise the whole question of the value of instructions in perceptual learning, and the type of instructions which are helpful, than to lead to any definitive conclusion. It is necessary to caution the second experimenter particularly about giving specific information about the figures in the instruc-

tions. The first experimenter must also avoid gaining familiarity with the figures while his partner is drawing them.

Typical results are shown in Table I.

TABLE I. SCORES MADE IN THE PERCEPTUAL-LEARNING EXPERIMENT

(*a*) *Average number of trials required to draw the figures by instructed and uninstructed learners*

Figures	1	2	3	4	5	6
Group I —						
Instructed....	5.4	4.2	3.4	5.4	4.8	4.2
Uninstructed..	7.5	4.7	3.7	4.7	4.5	4.8
Group II —						
Instructed....	7.7	5.5	4.7	6.3	8.3	5.3
Uninstructed..	8.3	5.8	5.0	6.5	6.2	6.0

(*b*) *Number of errors made in drawing the figures*

Figures	1	2	3	4	5	6
Group I —						
Instructed....	137	110	48	161	118	97
Uninstructed..	180	122	72	145	93	126

It will be seen that the instructed learners do better than those who are uninstructed, except in figures 4 and 5, and that the uninstructed do better in these two figures, except in one case. By reference to the copies of the figures in the Appendix it appears that figures 4

and 5 differ in an important respect from the others. Instead of beginning with a straight line these two figures begin with a curved line. It is tempting to conclude from these limited data that instructions *may* be of such a nature that, while they prepare the learner to cope better with a specific sort of problem, they impair his facility in dealing with a problem of a slightly different sort.

Extension of the experiment. The testing of this hypothesis by varying the instructions and the nature of the figures would be an interesting form of variation of this experiment.

The conditions of the experiment might be varied also in other ways. Instead of setting before the subject a figure that is to be copied, some piece of mechanism, such as a lock, or a natural object such as a feather, might be set before the subject with the requirement that he make a diagram which would show the working relation of the parts. In the case of the feather a magnifying glass would have to be used so that the minute parts could be distinguished. Another type of variation would be the use of more complex figures. The study of age differences would give profitable results, as in the case of Experiment No. 1. With reference to the effect of instructions, comparison might be made, not only with uniform instructions, but also with instructions which were followed throughout a longer series of drawings.

QUESTIONS AND TOPICS FOR DISCUSSION

1. Compare the perception of a figure before and after it has been scrutinized in detail.
2. Mention all the types of analysis which were carried on in acquiring a mastery of the figure.
3. Compare the importance of the impression factor and the meaning factor in perception as illustrated in this experiment.
4. Describe the part which general ideas or concepts play in working up such a figure.
5. Give suggestions of methods to be used in developing such a perception.
6. What false assumptions may be made in education concerning the child's experience when a concrete object is presented to him?
7. What part does movement play in the development of perception? List all the movements you can that were used by the subject in this study.
8. Describe so far as you can the changes in the relation of motor responses to perception as the child grows older.
9. Compare language as a form of motor response with manual activities.

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See also, Judd, C. H. *Genetic Psychology for Teachers*, chaps. I and II, for a general discussion of the relation of the impression and meaning factors in learning.

Experiment No. 3

Learning of the Problem-Solving Type

Problem. Problems of the type represented in this experiment may in general be described as being of such a nature that a grasp of their essential elements and their relations will lead to an immediate solution without the intervention of a period of gradual progress or improvement in skill. The experiments which are here included are for the purpose of illustrating the process of analysis, which is the typical method in this kind of learning, and its relation to other types of learning. This experiment, as in the experiment on perceptual learning, is for the purpose of qualitative description and analysis of the mental process involved, rather than for quantitative treatment.

The two parts of this experiment may be performed individually. We shall compare the results of naïve procedure, and of procedure after a discussion of the nature of the problem. Let one of each pair of students who work together proceed according to the naïve method, and the other proceed according to the instructed method.

(1) *Naïve method.* According to this method the problem is presented in simple terms and the student is left to work it out without any discussion of the principles which are involved. The students who use this method should proceed at once to the directions

for the conduct of the individual experiments (see, below, "*a*. Puzzle-box experiment") without reading the discussion which follows in the next paragraph.

(2) *Instructed method.* The purpose of giving these additional instructions to part of the group is to determine whether or not a general notion of scientific method in attacking such problems as involve analysis enables one to attack them in a more efficient manner than otherwise. In attacking these problems endeavor to observe the following principles: —

(*a*) The problem to be solved should be thoroughly understood.

(*b*) If possible, the problem should be broken up into parts or stages and the difficulties located. The difficulties should then be attacked singly to eliminate those which can be easily solved.

(*c*) When the chief difficulty or difficulties have been located, the various possibilities which suggest themselves for its solution should be reviewed and if their feasibility cannot be otherwise tested, they should be actually tried out. In mentally reviewing the various possibilities, previously acquired general experience should be employed to avoid the consideration of absurd or impossible solutions. The general procedure is to choose for consideration suggested solutions in the order of their apparent probability, and then to trace the consequences of each, one at a time. Proposed solutions which are found not to work should not be reconsidered until every other possibility is tried out.

(*d*) The fact that a solution is possible should be kept in mind and the attitude of discouragement avoided. The mind should be kept in a calm and collected condition, and confusion and random guessing should be avoided.

a. Puzzle-box experiment

Material and method. The material consists of a box, the opening of which is kept closed by a series of fastenings. (See Fig. 3, on the next page.) The student, of course, should not study the figure before opening the box. The box should be opened as quickly as possible without breaking or unduly straining any of the fastenings. The time from the attacking of the problem should be taken, preferably with a stop-watch, and recorded. Introspections should be made of the manner of solving the problem.

Treatment of results. The subject should describe fully his experiences in solving the puzzle, touching such points as the part played by random movements, the clues which were discovered before any movements were made, the points at which a trial led to the correction of a previous hypothesis, and the extent to which the relation between the whole series of steps was clearly recognized.

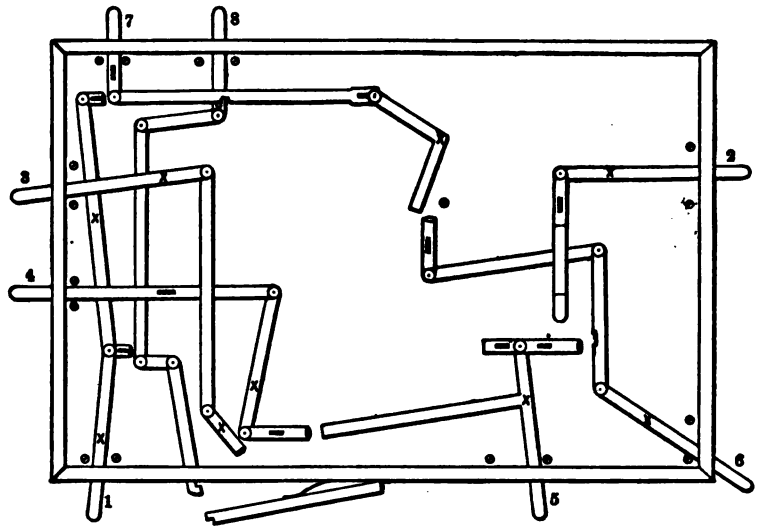

FIG. 3. DIAGRAM OF PUZZLE BOX

b. Problem of drawing a figure by continuous lines without retracing (Tait labyrinth puzzle)

Problem. The task before the subject consists in making an analysis of a two-dimensional figure so that it can be apprehended as consisting of a continuous line without retracing.

Material and method. The material is the figure used and described by Lindley in the article referred to at the end of the experiment, and which is reproduced in the Appendix. (The reference should not be read until after the experiment has been performed.) Let the subject begin his scrutiny of the figure immediately after making note of the time. As soon as he pleases he may attempt to draw the figure upon a blank sheet of paper in the manner required. The figure may be kept in view and referred to during the drawing. No attention need be paid to the technical excellence of the drawing. If the first attempt is successful, the time of finishing should be recorded. If not, the figure should be observed again, and so on until the figure is correctly drawn.

Treatment of results. The results should include the time taken for observation and drawing, the series of drawings themselves, and the subject's introspection of the process of analysis of the figure. The report should consist in a description of the method by which the problem was solved, based upon the introspections and a study of the drawings themselves. Such topics

should be considered as the relation between the amount of random trial and of analysis or planning; the products of the analysis, or the simpler figures into which the complex figure was broken up; particular parts which were found to be crucial; any abstract reasoning which was employed.

The general reports of both "*a*" and "*b*" should discuss individual differences in methods of procedure, in efficiency of learning, and any relation which may be found between method and degree of efficiency. The general resemblances between the results found by the different individuals and the differences between the results of those who proceeded by the naïve and the instructed methods should also be described fully.

Results of the experiment. The significant results from this experiment, as from the preceding one, consist very largely in the qualitative analysis of the learning processes in this type of problem. In general the wide difference between problem-solving learning and sensori-motor or perceptual learning may be recognized in the fact that the solution of a problem of the puzzle type may be due to a clear recognition of the relationship of the elements of the problem, even though some fumbling and haphazard guessing precede the recognition. The method is here distinguished from the result.

The objective record of the time required by the different members of the class, coupled with the introspective accounts of the methods used, throw light on

some of the facts of individual differences in time, method, and the relation of native tendencies or acquired habits to instructions in this type of problem. Table II gives the numerical results from the members of one class for both puzzles.

TABLE II. SCORES IN THE TAIT LABYRINTH AND PUZZLE BOX

(a represents the analytic method, t the trial and success method)

Instructed subjects					*Uninstructed subjects*				
	Puzzle box		*Labyrinth*			*Puzzle box*		*Labyrinth*	
Subject	*Method*	*Time*	*Method*	*Time*	*Subject*	*Method*	*Time*	*Method*	*Time*
1	a	0′ 50″	a	7′ 0″	1	a	0′ 50″	a	6′ 50″
2	a	1′ 25″	t	7′ 0″	2	a	1′ 3″	a	3′ 45″
3	a	1′ 45″	a	13′ 30″	3	a	1′ 10″	a	6′ 0″
4	a	2′ 30″	a	18′ 40″	4	a	1′ 30″	a	7′ 0″
5	t	2′ 15″	t a	9′ 0″	5	a	2′ 0″	t	12′ 30″
6	t	2′ 30″	a	11′ 30″	6	a	2′ 30″	a	14′ 30″
7	t	2′ 47″	a	5′ 30″	7	t	3′ 35″	t	48′ 0″
8	t	3′ 25″	a	9′ 25″	8	t	5′ 50″	t	38′ 0″
9	t	5′ 0″	t	3′ 30″	9	t	13′ 15″*	t	3′ 52″
10	t	5′ 40″	a	65′ 0″					
11	t	6′ 45″	a	14′ 0″					

Correlation between the time required to solve the puzzle box and the labyrinth (by footrule method). R .49.

* The subject was disturbed in his work and the time prolonged in consequence.

Several facts are clear, as far as conclusions can be drawn from these rather limited data. There is a very wide range between the time required by the slowest

and the fastest in both cases, the ratio being 8:1 in the case of the puzzle box (excluding one doubtful case), and 17:1 in the case of the labyrinth. The individual differences in the two kinds of problem correspond roughly, the coefficient (R) being .49. These individual differences are apparently so much greater than the difference which may be produced by brief instructions, such as were given in this experiment, that they render the effect of instructions undistinguishable as far as the time of performance is concerned. Instructions also appear to have had little effect upon the method used — except possibly in the case of the labyrinth.

Extension of the experiment. This suggests several tentative conclusions which could be tested by a further extension of the experiment. First, the instructions apparently were not followed, due to the fact either that some of the subjects were not accustomed to use the analytic method with this type of subject matter or that the analytic method was not their method in general. Second, the analytic method, when it was used, did not in several cases result in low time, perhaps because it was not properly understood or used, or simply because it was unaccustomed, or finally because trying to follow the instructions led to distraction and confusion.

Besides testing some of these hypotheses, further experimentation might be carried on with the detection of logical fallacies, or with problems in physics, mathematics, etc., making due allowance for differences in training.

QUESTIONS AND TOPICS FOR DISCUSSION

1. How far is the procedure of these experiments typical of the process of reasoning?
2. To what extent is the nature of the problem dependent upon the kind of subject-matter with which it deals?
3. Show with illustrations how the problems in this experiment differ from the problems of learning in the preceding experiments.
4. What are the conditions of efficient learning in this type of problem?
5. Do they differ from the conditions of efficient learning in Experiments Nos. 1 and 2?
6. Is it more helpful to identify or to distinguish between the various types of learning?
7. Give illustrations of problem-solving in school activities.

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Experiment No. 4

Transfer of Training in Sensori-Motor Learning

Problem. It is important to determine, not only to what extent and by what methods efficiency in various sorts of activities may be increased by practice, but also to what extent and by what methods the efficiency gained through practice in one activity may result in increased efficiency in other activities than those in which the practice is carried on. It has been said[1] that habits cannot, in the nature of the case, be transferred. The question cannot thus be solved by definition, however, but must be attacked by a study of individual habits.

Material and method. In this experiment we shall make a further study of the sensori-motor habit which was investigated in Experiment No. 1. The conditions of the experiment make it possible to change various factors in the problem in a variety of ways. First, we may use a different card, but keep the mirror in the same position. Second, we may keep the same card, but change the position of the mirror. Finally, we may change the position of both the mirror and the card.

In order to determine whether the effect of these changes is due to the general nature of the change or

[1] See Bagley, *Educative Process*, chap. xiii.

to some accidental feature of the cards, or the relation of card and mirror, there will be two sets of changes used, each of which consists of changes of the general nature outlined above. One member of each pair should follow Series I, and the other Series II.

Series I: —

Set 1. Card No. 1 with cross below, mirror parallel to long side of base. (This arrangement was used in Experiment No. 1, and is not to be repeated here. Those who used this arrangement before should be the ones to complete this first series.)

Set 2. Card No. 2 with cross below, mirror in same position as in Series I, 1.

Set 3. Card No. 2 with cross below, mirror parallel to left side of base.

Set 4. Card No. 2 with cross toward the left side of base, mirror at 45 degrees to sides of the base and at the left of the figure.

Series II: —

Set 1. Card No. 1 with cross below, mirror parallel to left side of base. (Not to be repeated here. Those who used this arrangement in Experiment No. 1 to complete Series II).

Set 2. Card No. 2 with cross below, mirror in same position as in Series, II, 1.

Set 3. Card No. 2 with cross below, mirror parallel to long side of base.

Set 4. Card No. 2 with cross to the right (away from the left edge), mirror at 45 degrees to sides of the base and at the left of the figure.

Twenty-five trials should be made with each of the three positions of the cards and mirror, as in Experiment No. 1.

Treatment of results. The numerical results should be presented in a table and charted as in Experiment No. 1. The curves of progress of the four different series should be brought together on one chart for comparison.

The report should include a detailed discussion of the relation between the curves of the different series, and of the kind and degree of transfer which appears. For the purpose of furnishing a basis for explanation of the facts of transfer, the nature of the change which was made from one series of trials to another should be analyzed. The mechanism of the apparatus should be studied, and the relation of the hand movements and of the apparent movement of the pen in the various series should be described.

The general report should include a discussion of the same matters as the individual reports on the basis of the wider range of material, and should particularly trace individual differences.

Results of the experiment. This experiment throws light on the existence and the conditions of transfer of training in sensori-motor learning. It does not purport

to demonstrate that there is transfer of other sorts of training, or to indicate what the character or conditions of such transfer may be. It is desirable to keep this in mind in interpreting the results of experimental

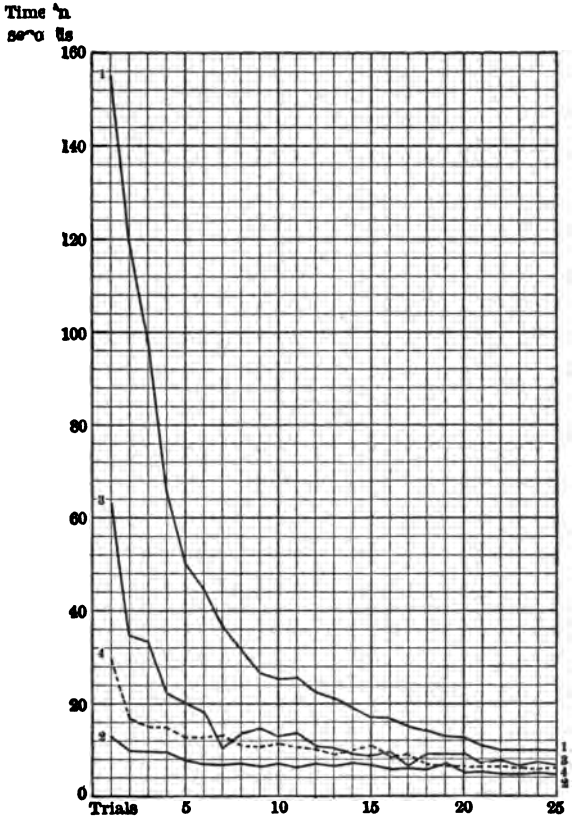

CHART III. LEARNING CURVES IN EXPERIMENT NO. 4

investigations of transfer, and to avoid applying their results to other kinds of activities than those which have been subjected to study. It is probable that no one or two formulæ will explain the facts.

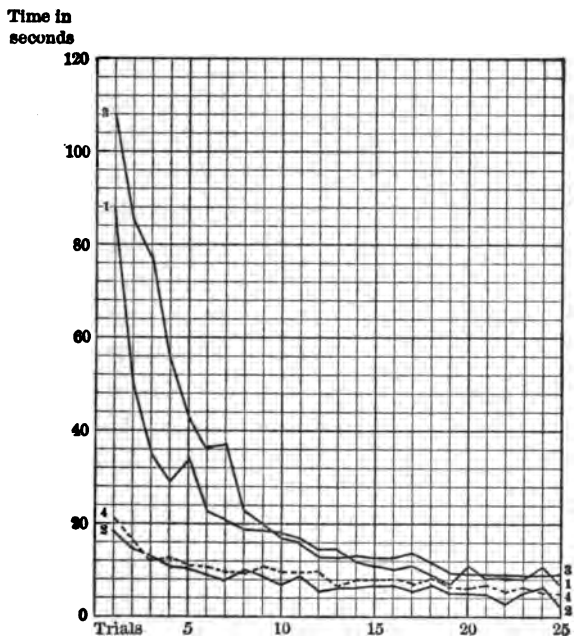

CHART IV. LEARNING CURVES IN EXPERIMENT NO. 4 (SECTION A. SERIES II)

The two charts, Nos. III and IV, represent graphically the average results from two sections of twelve and eight individuals respectively. Curve No. 1 in each case is taken from Experiment No. 1. The results

from two other sections are similar in the main features, as are those from the individual learners. The four series of twenty-five trials are numbered to correspond to the directions.

If we had only the results which are represented in one or the other of these two figures alone, it would be difficult to say with any certainty that the difference in the speed of performance in the four groups of trials was due in any measure to transfer. It might be due wholly to a difference in the difficulty in the adjustment required by the various arrangements of cards and mirror. Some such difference apparently exists, since the corresponding curves differ somewhat in the two series. This same difference appears also in the other two groups of subjects. But, in spite of these differences due to different degrees of difficulty in the coördination of the individual sets of twenty-five trials, there are likenesses in the transition from each set to the succeeding sets which must be due to some more general factor. That the difference in the rapidity with which the set is learned is not due to the character of the adjustments in each set taken alone is clearly demonstrated by the fact that the adjustment in Series I, 2, is exactly the same as that in Series II, 3; and that Series I, 3, is identical with Series II, 2. By reference to the charts it will be seen that precisely the same adjustment is made rapidly in Series I and slowly in Series II, while another adjustment is made slowly in Series I and rapidly in Series II. To explain these

differences there must be some general factor, based on the effect which carries over from one series to the next. In both Series I and II, the second set of twenty-five trials is made much more rapidly than the first. There is evidently positive transfer from Set 1 to Set 2. In both cases also there is strong negative transfer from Set 2 to Set 3, and positive transfer again from Set 3 to Set 4.

The details of the rest of the formulation of results are left to the student. The interpretation may be made along the following lines. Charts should be made which show the direction of the hand movements in tracing the successive lines of the figure, and also the apparent direction of the movements of the pen as they are observed in the mirror. From a study of these diagrams several significant facts can be gained. It will be found that in one case the hand movements in two successive sets of twenty-five trials are identical, furnishing an identical element. Between two other successive sets the apparent direction of the pen movements as seen in the mirror are identical — another identical element. The interesting further fact will be discovered that in one of these cases the transfer is positive and in the other negative. An identical element can either facilitate or interfere. In another case in which both elements change there is marked positive transfer.

Let us next examine into the relationship of the perceptual and motor elements in the successive series. In

this respect we shall find, by a study of the diagrams which were mentioned in the preceding paragraph, that there are certain general similarities between the series between which there is positive transfer, and differences between those between which there is negative transfer. Every movement of the hand or apparent movement of the pen may be considered with reference to the upward and downward and the right and left directions. There are then four general directions possible: Upward to the right or left, and downward to the right or left. Knowing the direction (stated thus in terms of the quadrant in which it falls) of each hand movement and apparent pen movement, the hand and apparent pen movements may be described as similar or different with reference to the upward and downward or the left and right directions. Thus the two movements ↗ and ↖ are similar in upward and downward direction, and different in right and left direction. Using these general descriptive terms the relation between hand and apparent pen movements is shown in the following tabular statement: —

	Series I		Series II	
	In upward and downward direction	*In right and left direction*	*In upward and downward direction*	*In right and left direction*
Set 1.	Same	Different	Different	Same
Set 2.	Same	Different	Different	Same
Set 3.	Different	Same	Same	Different
Set 4.	Mixed. First three strokes nearly opposite (different in both directions), and last three strokes in nearly same direction.		Same as Series I	

It is clear that the relations between the hand movement and the apparent pen movement in Sets 1 and 2 in each main Series (I and II) are of the same genera nature, though of course the directions are not identical, while between Sets 2 and 3 in each case the relations are radically modified. Set 4 is a special case, the relations being mixed, and probably profits from all the preceding series.

Let the student work out these facts in detail and state the results of the experiment in general terms, so as to indicate the relationship of the new coördination which was developed in the first series to that which is used under ordinary conditions of life, and the relation of the succeeding coördinations to those preceding.

Extension of the experiment. Many profitable variations of this experiment may be made. The order of the trial series may be changed to study different relationships and to compare the difficulty of the various arrangements. An interesting test would be to place No. 4 first. Entirely new positions of the mirror may be tried out. The practice series may be extended so as to measure greater refinements of skill. For this purpose some more exact measure of accuracy may be used. The transfer effect in the case of children in this type of learning may be compared with that in the case of adults. Finally other experiments, such as the card-sorting experiment of Bergström,[1] or a substitution

[1] J. E. Bergström, "The Relation of the Interference to the Practice Effect of an Association"; in *American Journal of Psychology* (1894), vol. VI, pp. 433–42.

test, changing the symbols at intervals, may be made.

QUESTIONS AND TOPICS FOR DISCUSSION

1. What kinds of transfer are shown in this experiment? Explain any differences which appeared in the relation of the different series.
2. Which of the proposed explanations of transfer seems best to explain the transfer found in this experiment? Consider, for example, identical elements; generalization, or the discovery of general principles; the concept of method; the development of ideals; the training of attention; the application of old habits in new situations.
3. Give illustrations from everyday activities of facilitation or interference through identity of movements or of perceptual elements.
4. Would you expect one formula to explain transfer where different mental processes are involved?
5. Would you expect transfer to be greater or less in the case of higher mental processes?
6. Give illustrations of transfer in the training given in the school through any of the processes mentioned in question 2 that you think can bring it about.

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Experiment No. 5

THE FACTORS IN MEMORY AS REVEALED IN ROTE MEMORIZING

Problem. The purpose of this experiment is to determine the factors in memorizing which are of importance in making certain methods more efficient than others. To simplify the problem, we first study rote memorizing, in which the associations of meaning are largely absent and in which learning depends on associations of an arbitrary sort. Nonsense syllables have been found to be most useful for the study of this kind of memorizing.

The first problem we shall attack has been investigated for the purpose of determining the best method of presenting words in the teaching of spelling.[1] The problem as it has been studied is whether it is best to present words to the pupil visually, orally, by having him speak the words or write them, or by some combination of these processes. It is not worth while to repeat these tests in order to settle the question in this form, since it has been sufficiently well demonstrated that the best method in general consists in a combination of the various sorts of presentation. The question we shall study is how far the most advantageous type of presentation is dependent on individual differences.

[1] See Meumann and Lay, in the References at the end of the experiment.

In particular we shall compare oral and visual presentation.

The second problem is concerned with the value of artificial associations in learning material which has no inherent associations of meaning. In other words, we shall study the value of mnemonic devices.

The third problem concerns the effect of the degree of thoroughness with which material is learned upon the permanence of the associations.

The fourth problem concerns the effect of attempting to recall at intervals during memorizing.

Material and method. The series of syllables to be memorized are printed on cards which, except in oral presentation, are shown in turn to the subject by the experimenter. The lists of syllables used are given in the Appendix. The set of cards is held on the table facing the subject and the successive cards are exposed by shifting the cards one at a time from the front of the pack to the back. The rate of presentation is one in two seconds, and is governed by the beat of a metronome. The series should be presented without a pause between the trials until the series is learned.

Unless otherwise indicated, the method is to continue to present a series until the subject is able to anticipate each syllable before it appears. The series is then considered to be learned to the threshold. The number of repetitions should be recorded by the experimenter. The number, including the final presentation which demonstrates the fact that the series is learned, measures inversely the rate of learning.

1. In order to determine individual differences in the relative ease with which series of syllables are learned by oral and visual presentation, let Series I be presented by pronouncing the syllables distinctly at a two-second interval, governed by the metronome beat. Since the experimenter becomes familiar with the syllables in oral presentation, a second series, No. I*a*, is provided, which is to be used for the oral presentation to the second subject. Series II may be presented visually as described above.

2. The relative value of the methods which are to be examined in the remaining parts of the experiment will be studied by dividing the class into two sections, and having one section proceed by one method and the other by the second method. The division of the class is to be made in each case by letting one member of each pair use one method, and the other member the other method. The performance of each group may be judged by comparison with their performance in the first part of the experiment, in which all pursued the same method.

In this part of the experiment we shall compare the efficiency of learning in which no special device is used, with learning according to the directions given below. Series III should be used. Those who are to use the uninstructed method should learn by the ordinary visual presentation, and should *not* read the following paragraph.

Many devices have been used to assist the formation

of associations which are devoid of meaning. Such methods are of use in memorizing dates, names, street and telephone numbers, etc. The common feature of such mnemonic devices is an artificial system of associations which forms a framework or skeleton into which the elements to be learned may be set. For example, in the present case the alphabet furnishes such a framework. For one who thinks easily in visual images, the letters of the alphabet may be thought of as arrayed in serial order, in a series of columns, or in some other convenient arrangement. As each syllable is presented, it may be placed in this framework according to the initial letter. Another method is to imagine the syllables to be arranged in groups — as in three groups of five. Each syllable of each group could then be placed and associated with its place. For one who thinks more readily in terms of auditory images, some form of sound associations may be used. For example, the initial letters of groups of successive syllables could be associated according to their sound, and perhaps related to some word. Rhythm is very helpful in forming auditory associations and should be taken advantage of. Some will find it more advantageous to group by threes, others by fours, or fives.

3. The purpose of the third part of the experiment is to compare the permanence of memory of a series of syllables which are learned to the threshold, as described above, with the memory of a series learned beyond the threshold. Learning beyond the threshold is

to be accomplished by the subject's repeating the series orally five times after the threshold has been reached. The syllables should be spoken in a low tone and the experimenter should move away to avoid becoming familiar with the series. The permanence of memory of both the series which have been learned beyond the threshold, and those which have not, is to be tested by the so-called saving method. Let the series be relearned on the following day by the same method of presentation as before, and the difference between the number of presentations necessary on the two occasions found. This difference represents the saving effected, and the saving is a measure of the permanence of memory. The class is to be divided as before, one half using one method and the other half the other method. Series IV should be used.

4. The fourth comparison to be made is for the purpose of measuring the value, as a method in memorizing, of attempting to recall the series before the threshold has been reached. Let half the class as before learn in the usual manner, and the other half proceed as follows. Make an estimate, on the basis of the results of the work already done, of the number of exposures which are likely to be needed to learn this, the fifth series. When half the estimated number of presentations have been made, stop for a moment and attempt to recall the series silently. Present the series and test the memory by the method of anticipation as before. Continue to attempt to recall the series after

each presentation. The permanence of memory should be tested as in Part 3.

In all but the oral presentation, the experimenter should avoid gaining any familiarity with the syllables of the series. The cards may be identified by the numbers on the back. The subject should make no comments which would indicate to the experimenter what the syllables are.

After each series has been learned, the subject should immediately make a note of any observations he may have made concerning the method by which the learning took place. He should make note particularly of any devices which are used in the learning.

Treatment of results. In the individual reports the obvious comparisons suggested in the description of the method of procedure should be made and discussed. The numerical results should be presented clearly in the form of a table. The questions and topics given below should be considered. In the general report these comparisons should be generalized and, in addition, individual differences in (*a*) the average number of presentations necessary for learning, (*b*) the kind of presentation or method which is most favorable to learning, (*c*) the permanence of memory and the relation of degree of permanence to the rate of learning should be given. These facts should be displayed in appropriate tables.

TABLE III. NUMBER OF PRESENTATIONS NECESSARY FOR THE INDIVIDUALS OF ONE GROUP OF SUBJECTS

Individual	Series I and Ia	Series II	Series III				Series IV				Series V						Average first learning	Average relearning
							To threshold		Beyond threshold		Continuous presentation		Recall					
	Auditory	Visual	Uninstructed	Difference	Instructed	Difference	Learning	Relearning	Learning	Relearning	Learning	Difference	Relearning	Learning	Difference	Relearning		
A	20	....	....	....	11	....	....	....	7	3	....	....	....	6	....	....	11.0	3.0
B	61	48	33	−15	....	....	....	....	16	3	13	−35	8	....	....	....	24.2	5.5
C	26	26	....	....	18	−18	....	....	32	4	....	....	....	17	−19	3	25.8	3.5
D	18	15	....	....	19	+ 4	....	....	12	3	....	....	....	10	− 5	2	18.6	2.5
E	18	14	12	− 2	....	....	....	....	10	4	11	− 3	4	....	....	....	11.8	4.0
F	57	26	30	+ 4	....	....	....	....	22	2	....	....	....	10	−16	2	31.0	2.0
G	23	11	....	....	9	− 2	8	4	....	....	....	....	....	6	− 5	3	11.4	3.0
H	16	12	21	+ 9	....	....	21	5	....	....	15	+ 3	6	....	....	....	17.0	5.5
I	9	15	....	....	11	− 4	....	....	8	2	6	− 9	3	....	....	....	9.8	2.5
J	17	12	....	....	15	+ 3	....	....	8	5	9	− 3	....	....	....	....	12.2	5.0
K	21	19	....	....	26	+ 7	....	....	17	3	12	− 7	1	....	....	....	19.0	2.0
L	15	13	....	....	17	+ 4	....	....	20	5	....	....	....	13	....	5	15.6	5.0
M	18	31	....	....	29	−12	12	10	....	....	....	....	....	11	−20	10	20.2	10.0
N	12	9	7	− 2	....	....	....	....	3	....	....	....	....	3	− 6	2	6.3	2.0
O	18	12	13	+ 1	....	....	....	4	....	....	....	....	....	8	− 4	....	12.7	4.0
P	31	25	....	....	14	−11	13	6	....	....	10	−15	6	....	....	....	18.6	6.0
Q	22	16	18	+ 2	....	....	....	....	12	2	....	....	....	8	− 8	1	15.2	1.5
R	51	36	....	....	54	+18	....	....	31	4	....	....	....	16	−20	4	37.6	4.0
Average	24.5	20.6	19.1	−.43	20.3	−.1	13.5	5.8	15.2	3.3	10.9	−9.9	4.7	9.9	−10.3	3.6		

TABLE IV. NUMBER OF PRESENTATIONS NECESSARY FOR EACH INDIVIDUAL OF A SECOND GROUP IN THREE SERIES

Individual	*Series I and Ia*	*Series II*	*Series III*			
	Auditory	*Visual*	*Uninstructed*	*Difference*	*Instructed*	*Difference*
A.....	13	8	9	+ 1	..	..
B.....	15	10	14	+ 4	..	..
C.....	16	18	9	− 9	..	..
D.....	21	18	11	− 7	..	..
E.....	22	16	..	..	15	− 1
F.....	23	10	..	..	8	− 2
G.....	23	27	..	..	6	−21
H.....	24	14	13	− 1	..	..
I.....	28	18	..	..	28	+10
J.....	32	17	21	+ 4	..	..
K.....	40	34	..	..	20	−14
L.....	49	17	15	− 2	..	..
M.....	61	48	33	−15	..	..
N.....	78	36	..	..	19	−17
Average...	31.8	20.8	15.6	−3.1	16.0	−7.5

Results of the experiment. Specimen results from this experiment are shown in Tables III and IV. Not much reliance can be placed on some of the results, since some of the members of the class failed to follow instructions carefully. There are some fairly clear outstanding facts, however.

By reference to both groups it appears that the series were learned more quickly by visual than by auditory presentation by the majority of the subjects. Only individuals C, D, E, I, and M of Table III, and C and

G of Table IV, learned more rapidly by auditory presentation. While the visual presentation proved to be the better on the average and for the large majority of the cases, the exceptional individuals must not be overlooked nor looked upon as abnormal.

Apparently the instructions did not have a marked effect upon the rapidity of learning. While the instructed group of Table IV gained over twice as much in Series III over Series II as did the uninstructed group, in Table III there was no appreciable gain by either group. This may be due to several reasons. There was some indication that the uninstructed group hit upon some of the devices mentioned in the instructions independently. The extent of individual and accidental differences may have covered up real differences due to instructions. The instructions may not have been of the best. More prolonged practice may be necessary to profit by instructions. These possible explanations should be experimentally tested before it is concluded that instructions are of negligible importance. This furnishes problems for further extension of this experiment.

Learning beyond the threshold evidently produces greater permanence of learning, as is to be expected. The extent to which learning should be carried beyond the threshold is evidently to be determined by the purpose in learning, — by the degree of permanence that is desired.

While attempting to recall during learning did not,

according to the figures of Table III, lower the number of presentations necessary in comparison with continuous presentation, it did produce somewhat greater permanence. The results from other groups commonly come out in favor of the method of attempting to recall at intervals, both in the number of presentations necessary for first learning and for relearning.

The averages in the last two columns of Table III bring to light individual differences in rapidity of first learning and of relearning, and in the correlation between rapidity of learning and permanence. In order to make the inspection of the table easier the scores may be arranged in ascending order. This is done in Table V. Very large individual differences appear both in the first learning and the relearning, the ratio of the lowest to the highest score being about 1 to 6 and 1 to 7 respectively. This is a very large difference among individuals of a group who are rather homogenous in training and general ability.

The calculation of a correlation coefficient is not in this case a very profitable proceeding as a means of measuring the degree of correlation, since the group includes several classes of cases, each characterized by a different relationship of speed of learning to retention. As a very rough method of indicating the degree of correlation in general, however, we may average the relearning scores of the top, middle, and bottom thirds of the whole group, classified on the basis of the first learning scores. The averages of the relearning scores

TABLE V. SCORES IN FIRST LEARNING AND IN RELEARNING

	First learning	*Relearning*	
A	6.8	2.0	
B	9.8	2.5	
C	11.0	3.0	
D	11.4	3.0	
E	11.8	4.0	
F	12.2	5.0	Average, 3.25
G	12.7	4.0	
H	13.6	2.5	
I	15.2	1.5	
J	15.6	5.0	
K	17.0	5.5	
L	18.6	6.0	Average, 4.1
M	19.0	2.0	
N	20.2	10.0	
O	25.8	3.5	
P	31.0	2.0	
Q	34.2	5.5	
R	37.6	4.0	Average, 4.5

show a slight tendency to increase with the increase in the first-learning scores, indicating a very slight tendency for the learning of rapid learners to be more retentive than that of slow learners — so far as this test goes. But the slightness of the correlation is shown by the fact that if the highest relearning scores of the middle and highest thirds were exchanged, namely, the 6 and 10, the averages of these groups would be 4.7 and 3.5 respectively.

A much more significant mode of examining such an array as this is to note the kind of cases which are rep-

resented. It is apparent, after a moment's inspection, that there are those of high, medium, and low retentiveness among the fast, the medium, and the slow learners. We cannot accept the traditional view that slow learners are more apt to be retentive than rapid learners. So far as there is a general rule the latter seems to hold. But no one type of correspondence appears to be general.

Extension of the experiment. This experiment may be extended by varying the conditions and the material in a variety of ways. The effect of instructions may be studied more fully, as already suggested. The effect of learning beyond the threshold on permanence, and the effect of attempting to recall on both speed and permanence may be studied by having the same individual use the various methods with different series. All the different devices may be tested with series of words, or with vocabulary pairs instead of with nonsense syllables. In such case the variability in the difficulty of material will be much greater. The effect of distribution of the repetitions may be studied by taking series of the same length or greater length, and making a few repetitions of each series at a sitting instead of carrying them to the threshold at one sitting. The effect of distribution on permanence is particularly important.

QUESTIONS AND TOPICS FOR DISCUSSION

1. Are any parts of the series learned before the rest? If so, account for the fact.
2. What accessory devices, if any, are used to aid learning? Do the stimuli arouse any form of imagery? If so, what form or forms? What function does the imagery have, if any, in the learning process?
3. Is it correct to assume that the imagery employed belongs exclusively to the sense through which the stimulus was given?
4. Is there a definite point at which memorizing may be said to be absolute or complete? If so, how may it be described? If not, how may degrees of learning be described?
5. Can the effect of learning in the early stages always be measured? Why does command of the material sometimes seem to deteriorate in the early stages?
6. An examination of recruits in Germany showed that they could recall little of what they learned in school. How is this result to be interpreted?
7. Give illustrations of the value of learning of various degrees of completeness.
8. Draw conclusions regarding the various factors or methods studied.
9. What is the effect of the formation of wrong associations?
10. Is rote memorizing in the school justified? Under what circumstances?

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Experiment No. 6

Memory for Sense Material

Problem. The problem of this experiment is to find the best method of memorizing sense material. Some of the same alternative methods tested in the experiment on rote memory might also be tried with logical memory. For example, one could determine the value of attempting to repeat the selection which was being learned before the memorizing was complete, or one might study the effect of memorizing beyond the threshold. In this experiment, however, but one phase of the problem will be attacked. The aim will be to determine whether it is better to memorize by the so-called part method, or the whole method. In using the part method, the learner memorizes a sentence or stanza or other small part at a time. In using the whole method one memorizes by reading the whole selection, or a fairly large part of the selection at one time. Instead of using the whole method in the strict sense, it will be more useful to modify it by dwelling somewhat longer upon the more difficult parts of the passage after they have been discovered. This is sometimes called the combined method.

Material and method. In this experiment each subject may work alone. While the memorizing need not be done in the laboratory, it should be done during the laboratory period in order to have the time of day uni-

form. In order that the material which is used by the class may be uniform, copies of a poem have been prepared. The selection is printed in the Appendix.

In order to compare the two methods in question, the simple procedure which is likely to suggest itself at first thought will not suffice. This method would be to spend first a certain amount of time in memorizing with one method, and then an equal amount of time using the second method, and compare the amount learned by the two methods. The difficulty with this procedure is that there is a decided improvement in memorizing with practice, which operates to the advantage of the second method used. This practice effect may be in a measure offset by using first method number 1, then number 2, and finally number 1, and averaging the rates of learning during the first and third periods by method number 1. Then, to make sure that the procedure is fair to both methods, still another precaution may be taken; viz., to let one half the class use the part method first and the other half the whole method. In the following plan, let *A* represent one of each pair of students working together, and *B* the other: —

A	*B*
Part method — 40 minutes	Whole method — 40 minutes
Whole method — 80 minutes	Part method — 80 minutes
Part method — 40 minutes	Whole method — 40 minutes

The work should be done in forty-minute periods, and should be distributed over two days. The whole

poem should be read once by all to get the general course of thought.

The material which is being memorized should be studied until it can be repeated once without error, at least so far as the learner can tell. When the part method is used, work should be continued until all the parts can be repeated continuously, and not merely as separate parts. If the material which is being studied is not quite finished at the end of the allotted time, the period may be extended. The efficiency of the methods is to be measured by the number of lines per hour which can be learned by their use. The subject should estimate, when using the whole method, the number of lines he can learn in the allotted time; but, if this amount is not learned, he should continue either then or on the next day until it is learned. If considerable time remains, he should learn another section.

In order to compare the efficacy of the two methods, with reference to permanence, the parts learned should be relearned at the end of a week and the amount of saving effected should be tabulated. Each part should be relearned by the same method that was used in first learning.

Treatment of results. Each student should describe in his report the order in which he used the methods, the amount of time devoted to study by each method, and should calculate and report the number of lines per hour learned by each method. The amount of improvement, if any, from the first to third period should

be calculated. The topics and questions given below should also be discussed.

In the general report, a table should be given which shows the lines learned per hour by each student in the various periods and by the two methods. Those who begin with the same method should be grouped together. The averages necessary to bring out the comparison of the two methods should then be calculated. The practice effect should also be calculated. A comparison of the degree of retention in the case of the fast and of the slow learners may be made.

Results of the experiment. The tabulated results of this experiment for one section of nineteen are given in Table VI. After the somewhat detailed analysis of some of the preceding experiments, the student may be left with a few indications of the outstanding facts in this table. He may then elaborate the details.

It appears, contrary to the principle which is generally accepted, that the part method gives better results on the average, and in the case of the majority of the individuals, than does the whole method. In some sections the whole method gives better results on the average, but there are still some individuals who do better with the part method. This so far as first learning is concerned. In the case of permanence of memory, as we should expect, the whole method makes a better showing, though even here some individuals do better by the part method. Let the student weigh the statement that we should expect the whole method

TABLE VI. RESULTS WITH WHOLE AND PART MEMORIZING

Whole — Part — Whole Arrangement

Individual	Whole		Part		Whole		Learning		Relearning		Effect of practice shown in	
	Lines pr. hr.		Lines pr. hr.		Lines pr. hr.		Av. lines pr. hr.		Av. lines pr. hr.			
	Learning	Relearning	Learning	Relearning	Learning	Relearning	Part	Whole	Part	Whole	Learning (per cent)	Relearning (per cent)
E	30	....	36	....	36	....	36	30	....	....	..	....
G	66	....	75	....	78	....	75	72	....	....	.18	....
J	36	72	49	111.5	60	240	49	48	111.5	156	.67	2.33
L	61	....	60	....	44	....	60	53	....	.....	−.28	....
M	48	180	49.5	182	57	285	49.5	52.5	182	232.5	.19	.58
N	42	280	39	173	48	432	39	45	173	306	.14	.54
O	46.5	360	63	288	51.5	321	63	49	288	340.5	.11	−.11
R	115	960	96	576	75.5	165	96	95	576	562.5	−.39	−.83
S	48	157.5	53	112	58	143	53	53	112	140	.21	.04
Average	54.7	331.6	57.7	240.4	55.8	264.3	57.5	55.5	240.5	289.6	.09	.435

30
36
30
36
30

TABLE VI (*continued*)

Part — Whole — Part Arrangement

Individual	*Part*		*Whole*		*Part*		*Learning*		*Relearning*		*Effect of practice shown in*	
	Lines pr. hr.		*Lines pr. hr.*		*Lines pr. hr.*		*Av. lines pr. hr.*		*Av. lines pr. hr.*			
	Learning	*Relearning*	*Learning*	*Relearning*	*Learning*	*Relearning*	*Part*	*Whole*	*Part*	*Whole*	*Learning (per cent)*	*Relearning (per cent)*
A	36	....	21	....	39	....	37.5	21	.....	....	.083	...
B	30	240	36	267	30	300	30	36	270	267	....	.25
C	48	....	48	226	64	240	56	48	240	226	.333	.06
D	31.5	105	23.5	86	28.5	88	30	23.5	96.5	86	−.095	−.16
F	30	200	30	180	42	280	36	30	240	180	.40	.40
H	30	150	40	336	36	240	33	40	195	336	.20	.20
I	33	....	35.5	....	13.5	....	23	35.5	....	....	−.59	....
K	36	....	33	....	42	....	39	33	....	....	.17	....
P	30	160	41	320	45.5	372	39	41	266	320	.51	1.325
Q	36	....	37.5	....	36	....	36	37.5	....	....	....	....
Average	34	171	34.6	236	37.7	253.3	36.5	34.5	218	236	.10	.462

to be superior for permanence of memory, and argue for or against it.

It is possible that previous practice with the part method outweighs the inherent advantages of the whole method. This can be tested by inquiring into the previous habits of memorizing of the individuals who made better time by the whole and the part methods respectively; and by having some individuals, who do better by the part method, carry on more extended practice with the whole method to find out whether the advantage is reversed.

The correlation between speed of first memorizing and permanence of memory may be examined, as in the experiment with nonsense syllables. In the group under examination the same rule holds. While, in general, the rapid learners relearn more quickly, some of them relearn slowly and some of the slow learners relearn quickly.

Extension of the experiment. This experiment may be extended by carrying on more prolonged tests with a variety of materials; by experimenting with different amounts which are taken as sections to be learned as a whole — particularly with reference to the individuality of the learner and the difficulty of the subject matter; and by making the test with children of different ages under school conditions.

QUESTIONS AND TOPICS FOR DISCUSSION

1. What, in psychological terms, are the respective advantages of the two methods?
2. Do the objective results coincide with your experience in memorizing? If not, discuss the discrepancy.
3. If there was improvement with practice, try to explain on the basis of introspection the cause of the improvement.
4. Give directions for efficient memorizing.
5. How far do you think memory in general can be improved?
6. What are the limitations upon the conclusions to be drawn from a short experiment like this when applied to the general conduct of mental work?
7. Is there a contrast between the fast and the slow memorizers in their preference for the two methods?
8. Which method would be more likely to improve rapidly under intensive training?
9. Does this contrast between the methods of memorizing in the strict sense of the word apply to study in the broader sense?

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CHAPTER III

EXPERIMENTS WITH THE SCHOOL SUBJECTS

EXPERIMENT No. 7

EXPERIMENTAL PSYCHOLOGICAL ANALYSIS OF HANDWRITING

Problem: Analysis of the writing movement. As in the study of the learning process we began with a motor type of learning, so in the study of the psychology of the school subjects, we may begin with one which is predominantly motor in character. Such a subject is handwriting. From the point of view of the observer the writing process is a motor coördination. That is, it consists in a complex organized movement which is made up by the coöperation of a number of simpler movements. These simpler movements work together simultaneously in the production of the complex movement; and at each successive moment one particular combination of movements is followed by a different combination. In short, the simpler movements work together harmoniously, both simultaneously and in succession. This experiment will consist in an objective analysis of the writing coördination into several of its simpler components.

Material and method. The analysis of the movement into the contributory movement of the arm (in-

cluding movements about the elbow and shoulder, the wrist, and the fingers, may be made by means of an adaptation of the apparatus used in Experiment No. 1. In place of the handle, used in the former experiment, there is a rubber band which is to be placed around the palm of the hand in front of the thumb and just back of the third joints of the fingers. The point of attachment with the rod which transmits the hand movement to the levers should be situated at the highest point of the band. The tracer record of the hand is reversed, but may be compared with the writing by turning it upside down.

The experiment may be carried on as follows: First, place the two sheets of paper for the written and the tracer record with the edges parallel to the sides of the apparatus, and adjust the tracer so that it is comfortable and follows the movements of the hand closely. Now take a record of several words, written in one's ordinary speed and manner of writing. To make comparison easy, the same sentence may be written by all; for example, "A quick brown fox jumps over the lazy dog." Compare the tracer record and the writing so as to answer the following questions: —

1. To what component (element) of the total writing-movement does the arm and hand contribute most? To what element do the finger movements contribute?
2. To what extent does the arm contribute in the formation of the letters? In this respect the indi-

vidual differences among the members of the class should be particularly noticed.

3. Distinguish the movement at the wrist from the movement at the elbow or shoulder, if such distinction is shown by the record. Make another record, this time writing with as little finger movement as possible.
   a. To what extent were you able to exclude the finger movements?
   b. What modification, if any, was made in the appearance of the writing by the difference in the type of movement?

Make a record with the tracer of a series of ten or more straight up-and-down strokes to resemble a series of saw teeth. Then make a series of dots on the paper on which the writing is done in the same relative position as the upper and lower limits of the up-and-down strokes previously made, and make another record with the tracer of a series of up-and-down strokes, using the dots as limiting points. Compare the tracer records in the two cases and draw conclusions.

Treatment of results. The results of this experiment are not subject to exact quantitative treatment. The relative amount of hand movement used in the formation of the letters may be estimated by comparing the height of the letters themselves with the height of the corresponding part of the tracer record. The same may be done for the " saw tooth " movement. In de-

termining individual differences, the records may be put into classes roughly divided under such rubrics as little, medium, and much, — as for example in determining individual differences in the amount of arm movement used. The correlation between the amount of finger movement and the quality of the writing may be worked out.

Results of the experiment. The more significant results of this experiment cannot be expressed in tabular form. The report of such an experiment consists in the reproduction and interpretation of typical records. Three such records are shown in Figures 4 and 5. The following points should be observed and discussed in the report: —

It is evident there is wide individual difference in the amount of arm movement in comparison to finger movement in the three cases whose records are before us. In the case in which the finger movement is least in amount there is still a certain amount, particularly in the earlier words of a sentence. It is of importance to note that the additional amount of arm movement which can be introduced voluntarily is limited. Long-established habits are not quickly changed.

The tracer record is shorter than the written line in all cases, but more so in some cases than in others. Why is this? It is not due to the failure of the pen to follow the movements of the hand attachment. To work out this mechanical problem the various parts of the hand and arm should be diagramed. The solution of the

problem throws light on some of the details of the movement.

The slope of the line of writing and the slant of the

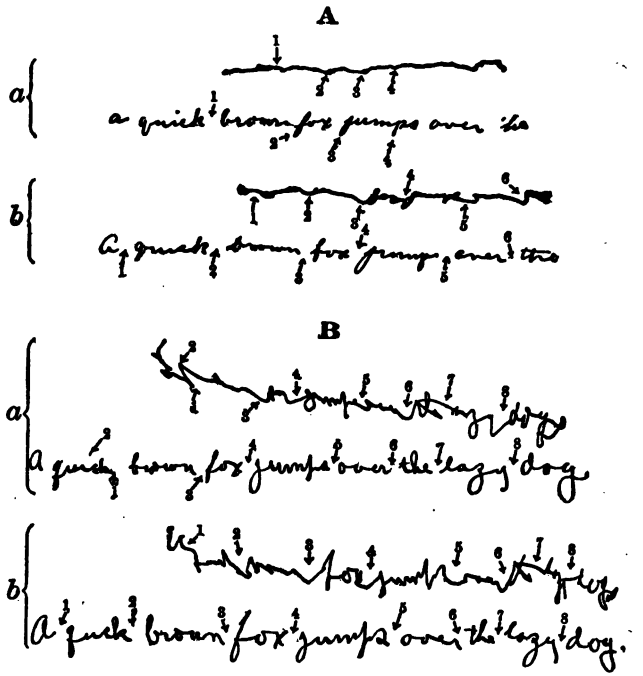

FIG. 4. TRACER RECORD FROM A WRITER WHO USES LITTLE (A) AND MUCH (B) ARM MOVEMENT

a. Written in the writer's usual manner
b. Written in an attempt to emphasize arm movement

individual letters is not always the same in the tracer record and the writing itself. Sometimes the slope of the tracer record varies from word to word. What

adjustment of hand, arm, or fingers explain these variations?

The three records used for illustration are not enough to form the basis for conclusions regarding the

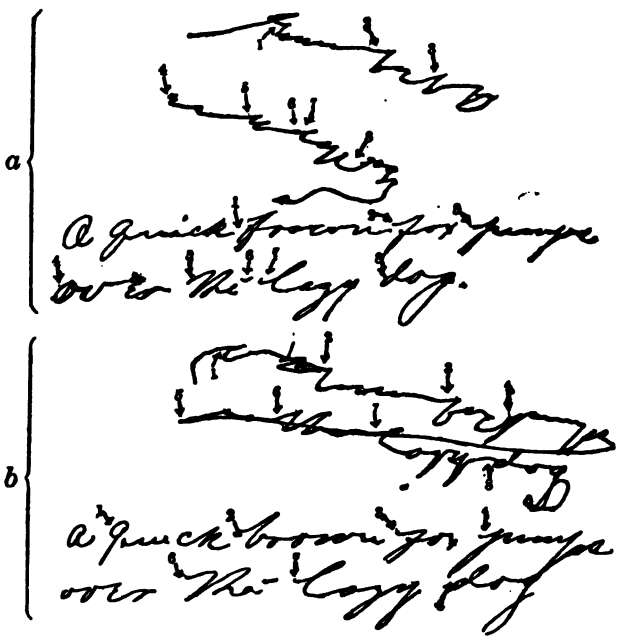

FIG. 5. TRACER RECORD FROM A WRITER WHO USES A MEDIUM AMOUNT OF ARM MOVEMENT

a. Written in the writer's usual manner
b. Written in an attempt to emphasize arm movement

relation of the character of the coördination to the character of the written product, though they offer suggestions on this point. We have been taught to as-

sociate arm movement with a particular style of writing which is taught in business colleges, and is being adopted in the schools. Such an association does not seem to exist in the specimens before us. This problem is of major importance, and should be studied more thoroughly on the basis of wider results from the whole class.

The results of the experiment with the saw teeth are easy to interpret, and need not be illustrated here.

An important part in any experiment in which apparatus plays a prominent rôle consists in testing the reliability of the apparatus. In the present instance, it is likely to seem to a good many writers who have learned the arm-movement style of writing that the apparatus does not faithfully represent their writing movement. The criticism may be raised that there is some play in the levers which makes the traced record less complete than the movement of the hand and arm. In an original experiment all such possible criticisms should be anticipated.

Extensions of the experiment. One form of extension of this experiment, then, may consist in determining the degree to which the movement of the pen reproduces the movement of the attachment of the band which goes round the hand. The test may be made roughly by holding the plate of the socket-joint firmly against a sloping pencil, and then tracing a figure with the pencil, taking care to keep the pencil at a constant angle to the paper and otherwise parallel to its position

at the start. A more exact method is to construct a small three-legged stand, about three inches high and with rounded feet, to make it slide easily, and a vertical tube in the center large enough to hold a short pencil. The ball-and-socket attachment of the hand-band may then be fastened to the top of the stand directly above the pencil, in such a manner that the joint moves freely, and a record made by sliding the stand over the paper. If the tracer record does not correspond closely to the record made by the pencil the apparatus should be examined to see if any joints are loose. The two records should be very nearly identical.

Another extension of this experiment, which may be made, is to conduct a practice experiment in the development of the arm movement, recording the progress by means of the tracer instrument. This will give some insight into the conditions of such a modification of a long-standing coördination, such as writing, and will give a basis for estimating the difficulty attendant upon the attempt to modify the handwriting habits of the pupils.

The writing coördination of pupils themselves may be analyzed by means of the tracer. Comparisons may be made between the writing of pupils of different degrees of maturity, or between groups who have been taught by different methods.

Another type of study of the writing coördination consists in a measurement of the speed and pressure-changes of the resultant total writing movement, in-

stead of the analysis of the component elements of the coördination. Such a study makes possible the determination of such features as the rhythm of the writing movement. Rhythm is present when the successive strokes are made in something like equal periods of time. In the young child's writing long strokes are made in much longer time than short strokes, while in an adult's writing the duration of long and short strokes may be equal. The determination of such facts as these requires some form of apparatus by which the speed of movement may be measured. The writer's article in the Psychological Monographs, cited in the list of references, describes an elaborate form of apparatus which may be used for this purpose. A simpler form could be set up, particularly if the pressure were not recorded, to make less accurate measurements. On the other hand, the pressure alone could be recorded by means of a relatively simple table, set upon a lever which was kept in position by a spring and records upon a kymograph drum.

QUESTIONS AND TOPICS FOR DISCUSSION

1. What conclusions may be drawn, if any, as to the proper function of finger, hand, and arm movement?
2. Do the results throw any light on the amount of individual difference in this respect which it is desirable to allow?
3. What bearing does the fact regarding the function of arm movement have upon the most desirable position of the paper and slant of the writing.
4. Make any observations you can upon other acts of skill, and note individual differences in the coördination.
5. In what degree can the makeup of the coördination be controlled by the teacher or the learner?
6. Distinguish between *form* and *execution* in an act of skill.

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Experiment No. 8

A TEST OF HANDWRITING

Problem. The grading of handwriting, either for the purposes of teaching or of supervision, is very uncertain because of the lack of a means of accurately judging its excellence. In making a judgment it is necessary to take into account all the characteristics which are essential to good writing. These include at least the speed with which the writing is produced and the quality of the writing itself. The speed can easily be measured by requiring the pupils to write, for a specified length of time, material which has been memorized. Quality is not so easy to measure, because of uncertainty as to what constitutes good quality and of the difficulty of finding means of measuring quality when it is defined. Thorndike, in constructing his measuring scale, used three characteristics for quality; namely, legibility, beauty, and character. Ayres used legibility alone. The two investigators agree in taking, as the basis of judgment, a general unanalyzed quality or group of qualities. The method of constructing their scales is different, but the method of applying them is the same; namely, to judge by the general impression which the writing makes. The scales help by giving standards by which these general impressions may be given numerical equivalents. The scale which is presented for trial in this experiment differs from the two

above mentioned in that one in using it does not attempt to compare the general impression made by the specimen to be judged with the impressions made by the specimens in the scale, but rather tries to analyze and rank the most important elements of the form of the writing which produce the impression of legibility, beauty, etc.[1]

The elementary characteristics of the writing which are assumed to constitute it legible, beautiful, etc., are four: (1) the degree of uniformity of the writing, (2) the quality of the line, (3) the correctness of letter formation, and (4) the spacing or composition. It is necessary to explain what is meant by these categories more fully.

Uniformity is applied particularly to two characteristics, slant and alinement, the latter including the height of the letters. It cannot be said that any particular slant is the best, but it is clear that the slant of any person's writing should be uniform. Variability in slant may be of various sorts. In the first place, it may be due to a general lack of coördination, so that the variability follows no rule. In the second place, it may consist in an increased slant toward the end of the line, which is due to the lack of corrective adjustment. Finally, it may be due to occasional readjustments in

[1] The Thorndike Scale can be obtained from the Bureau of Publications of Teachers College, Columbia University, New York City; The Ayres Scale from the Russell Sage Foundation, Division of Education, New York City; and the Analytical Scale from Houghton Mifflin Company.

the position of the hand or paper, the slant remaining fairly uniform between these readjustments. Similarly, the letters should come to a common base line, and the same kinds of letters should be of the same height. We may confine our attention, for convenience, to the one-space letters. It is not easy to grade uniformity of slant and of alinement together, so these two categories have been separated in the charts.

All the characteristics so far described might appear in a high degree of excellence, and yet the writing might be seriously at fault if the line itself were not clear and firm. The line should have evenness in width, indicating evenness of pressure upon the pen, or at least changes in width should not be great, abrupt, nor irregular. A moderate degree of even shading should not be penalized. The direction of the line also should not change in an uneven fashion, producing a wavy or jagged appearance and indicating lack of freedom, ease, and control of movement. The third category, therefore, is quality of line.

The fourth characteristic refers to the arrangement of the lines within the letter itself. In general the point to be judged is the degree of conformity of the letter formation to the standard letters. In applying this standard the judge must avoid using the peculiarities of any particular style of alphabet as a guide, and must try to distinguish the requirements on which all English alphabets would agree. For example, all would agree that the "o" should be closed, that the last

stroke of the " a " should come to the base line, that the " t " should not have a loop, etc. Perhaps the best way to judge this characteristic is to look through the writing and try to estimate rapidly the degree to which the letters are well formed and clear.

The fifth category, spacing, is somewhat more difficult to analyze and rank. The aim from this point of view may be said to be — first, to so place the letters and words on the page that the words themselves possess unity. The letters should be far enough apart to make them easily distinguishable, but should be close enough together to give the word a compact appearance. In the second place, the words should be related to each other much as the letters are related in the word. There should be enough space between the words on a line, and between the lines, to render each word distinct, but no more. The specimens on the chart illustrate the application of these principles.

Material and method. In order to aid in discriminating these different characteristics, and awarding to specimens grades according to their standing in each quality, a chart has been prepared. This chart is composed of five series of writing specimens, arranged in an ascending scale of excellence, each series representing one of the qualities which have been described. Thus the first series represents different degrees of uniformity of slant; the second series, degrees of uniformity of alinement and size; etc. Three degrees of excellence are distinguished in each chart. In all the

categories these are given scores of 1, 3, and 5 respectively. The intermediate scores 2 and 4 may be used. The scores for letter formation may be doubled, on the assumption that this characteristic is more important than the others. It is probably better to use the same scoring as in the others in making the judgments, and then double them afterwards.

The specimen to be judged is graded according to each category separately, and given the rank of the specimen in the chart with which it most nearly corresponds in each case. The total rank is calculated by summing the five individual ranks. Thus, if letter formation is given double value, the lowest possible rank is 6, and the highest possible rank is 30 (5, plus 5, plus 5, plus 10, plus 5), and the range is 24.

Several precautions are to be observed in making the judgments. The value of the method rests upon the fact that different features of the writing are singled out one at a time, and are graded by being given a rank in one of only three steps. The differences between the steps are marked, and the ease of placing a specimen should be correspondingly easy.

This method implies, however, that

(1) The attention is fixed on only one characteristic at a time.

(2) The judgment on one point be not allowed to influence the judgment on the other points.

(3) The same fault be counted only once.

(4) General impression be disregarded.

These four rules, in fact, express different aspects of the same precaution, but it is worth the emphasis thus given.

The experiment consists in judging, by means of the method which has been described, one hundred specimens of writing of different styles and from writers of different ages. (In order to give some preliminary practice, ten additional specimens should be provided which are to be graded first.) No marks are to be made on the specimens themselves. Each one is given a serial number, and a record is to be kept of the individual ranks as well as the final rank assigned to each specimen.

The individual reports should contain a table containing these data, together with the average rank assigned to the group of papers. Each individual should also put the ranks which he has assigned into a chart to show their distribution. (For example of a distribution chart, see the article by Starch and Elliott, in the *School Review* for April, 1913, p. 256.) In this case the units on the base line represent the possible ranks from 6 to 30. Above each rank should be written the numbers of all the papers which are assigned that rank.

Results of the experiment. The results obtained by the use of the analytic scale with untrained judges have not as yet warranted a positive statement as to the possibility of obtaining highly consistent results in the grading of writing by different graders. We may first examine the record of the scores given by one group of

ten graders to 50 specimens of children's writing, and then consider their significance. In Table VII are given the scores given by the ten graders to five of the papers, chosen so as to represent different degrees of excellence.

TABLE VII. SCORES OF TEN INDIVIDUALS GRADING FIVE WRITING SPECIMENS

Grader	*Specimen*				
	1	2	3	4	5
A	8	14	14	18	28
B	7	13	15	14	23
C	8	10	16	20	28
D	6	10	22	12	28
E	7	19	21	22	28
F	10	18	17	28	30
G	9	15	17	24	29
H	9	17	14	21	29
I	12	14	18	20	29
J	8	18	20	24	26
Average	8.4	14.9	17.4	20.3	27.8

The examination of this table makes it clear that there is a good deal of variation in the grades which different untrained individuals give to the same papers. In specimen 1 the range is from 6, the lowest possible rank, to 12. In specimen 4 the range is from 12 to 28.

TABLE VIII. AVERAGE OF THE GRADES GIVEN BY TEN GRADERS TO THE SAME FIFTY PAPERS, USING THE ANALYTIC AND THE AYRES SCALES

Graders	*Averages by analytic scale*	*Variations from general average*	*Averages by Ayres scale*	*Variations from general average*
1.....	18.2	.3	59.8	3.0
2.....	13.7	4.2	52.4	4.4
3.....	16.34	1.6	48.9	7.9
4.....	15.86	2.0	47.1	9.7
5.....	17.08	.8	58.0	1.2
6.....	19.05	1.2	63.1	6.3
7.....	19.86	2.0	60.1	3.3
8.....	19.8	1.9	56.8	0.
9.....	19.58	1.7	51.0	5.8
10.....	19.64	1.7	70.7	13.9
Average.....	17.9	..	56.8	..
Mean Variation..	..	1.74	..	5.6

The examination of the variation among the average of the grades given by the different graders to the whole set of fifty papers may be more encouraging. These averages are shown in the second column of Table VIII. The mean variation of these averages is 1.74 steps on the scale, the extreme range of which is 24 points. This variation is in both directions from the average, so that about half of the graders are 3.5 points or more apart in the average rank they assign to a group of fifty papers. For instance, in this group the third grader from the bottom assigns an average grade of 16.34, and the second from the top 19.8. This dif-

ference of 3.5 points is about equivalent to the average progress made in two school years. In the case of another group of fifteen graders the variation was considerably less, being 1.49.

A study has already been made of the variability of graders using the Ayres scale. See the article by Manuel, cited in the list of references. In the present experiment a similar test was made and the final results are shown in the last two columns of Table VIII.

The question which immediately arises is, Which of the two variabilities, 1.74 or 5.6, is the greater? We cannot determine merely on the basis of the amounts taken at their face value, since they are based on entirely different units. Various means of equating such coefficients of variability have been used or suggested. See the articles by Starch,[1] Weiss,[2] Pintner,[3] and Kelley.[4]

The most reliable method is the one which takes, as the measure of the units which are used, the actual range among specimens which are graded in terms of these units. If the same specimens are graded by two scales, and are distributed according to the scores

[1] Starch, D. "The Measurement of Handwriting"; in *Journal of Educational Psychology* (1913), vol. 4, pp. 445–64.

[2] Weiss, A. P. "A Modified Slide Rule and Index Method in Individual Measurements"; in *Journal of Educational Psychology* (1914), vol. 7, pp. 190–225.

[3] Pintner, R. "A comparison of the Ayres and Thorndike Handwriting Scales"; in *Journal of Educational Psychology* (1914), vol. 5, pp. 525–36.

[4] Kelley, T. L. "Comparable Measures"; in *Journal of Educational Psychology* (1914), vol. 5, pp. 589–95.

which are given to them, we may assume that the range of one distribution roughly represents the same range in merit that is represented in the other. Since extreme cases are likely to be somewhat unreliable, we may take the extent of the middle half (approximately) of each distribution as representing equal ranges in merit. Thus, in the present case, the score of each of the fifty papers on the Analytic and Ayres Scales (based on the average of the rankings of the ten graders) is as follows: —

COMPARISON OF SCORES, USING

Analytic scale	*Ayres scale*	*Analytic scale*	*Ayres scale*
8.4	24.0	17.4	56.5
10.8	31.5	17.5	58.5
11.2	37.5	17.7	58.5
12.8	39.5	17.8	59.0
13.4	41.0	18.0	59.0
13.4	42.0	18.2	60.0
13.7	42.5	18.3	60.0
14.0	43.5	18.3	61.0
14.1	44.5	18.6	61.0
14.4	45.0	19.5	61.0
14.8	45.5	19.6	62.5
14.9	46.5	20.3	64.0
14.9	48.5	20.3	65.5
15.0	49.0	21.6	65.5
15.0	49.0	21.9	67.5
16.0	50.0	22.5	68.5
16.1	51.0	22.9	71.0
16.2	52.0	23.4	73.5
16.4	52.5	23.7	73.5
16.5	52.5	23.9	75.0
16.6	53.0	24.1	75.5
16.6	53.0	25.0	77.0
16.8	53.5	26.1	79.0
17.1	54.5	27.5	83.0
17.1	55.0	27.8	88.0

The scores are arranged in ascending order in each case, and the scores which correspond in position in the two series do not necessarily represent the same paper.

The assumption in this particular case is that the range 14.9 to 20.3 is approximately equivalent to the range 48.5 to 65.5 or, in other words, that 20.3–14.9, or 5.4 units on the analytic scale, are approximately equivalent to 65.5–48.5, or 17 units on the Ayres scale. One unit on the analytic scale is then equivalent to 3.15 units on the Ayres scale.

We are now in a position to equate the two coefficients of variability, 1.74 and 5.6, by multiplying 1.74 by 3.15, and thus turning it into equivalent units. The variability turns out to be 5.48 by the analytic scale, as compared with 5.6 by the Ayres scale.

Neither of these is satisfactory if we are to compare ratings made by different investigators, unless we have each set of papers rated by a group of judges. Preliminary tests have indicated, however, that a much more reliable set of judgments may be obtained by the analytic method when the judges are trained for their task. This requires ample discussion by a group of graders upon the first few papers they grade. After a careful study and comparison of their grades upon twenty-five papers, the variation becomes inconsiderable. Practice, with conferences, also greatly reduces the variability in the use of the other scales. (See Gray's article referred to below.)

Extension of the experiment. This is one type of extension of this experiment that could profitably be made. One might, if successful, go still further, and determine whether judges might be trained by using a set of printed instructions accompanied by a set of papers and their standard ratings.

Further extensions of this experiment may be made by using some of the scales which have been developed in other subjects, and testing their reliability. The list of references below indicates directions in which further study might be made. Finally, the attempt may be made to work out and standardize an analytic scale for the measurement of attainment in some other subject of the curriculum.

QUESTIONS AND TOPICS FOR DISCUSSION

1. Discuss fully the adequacy or inadequacy of this method of testing handwriting.
   a. Were any categories less satisfactory than others?
   b. Is the list of important categories complete?
   c. Are any particular specimens unsatisfactory?
   d. Is the use of the method unduly cumbersome?
   e. Compare the method with those of Thorndike or Ayres if you have used them.
2. How might such procedure lead to a better appreciation of the qualities of good writing?
3. How might such a method help the teacher in teaching?
4. How reliable is the method for comparing different grades or schools? (The general report should include an especially full discussion of this question.)
5. Add any suggestions which occur to you.
6. Does an analytical scale require any more training for its satisfactory use than one which requires judgment from general impression?
7. Is there any other method than that used by Gray (Texas

bulletin) of determining the relative importance of the various categories? What is it?

8. Look up, if you can, the method of grading some agricultural product and give a sample score card.

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EXPERIMENT No. 9

OBSERVATION OF EYE MOVEMENTS IN READING

Problem. In reading, as in writing, we shall begin with the study of the motor coördination, as the process of reading depends upon the formation of motor habits, just as does writing.

Material and method. For the accurate study of eye movements it is necessary to resort to some mechanical means of recording them, such as the mechanical recording device described by Huey, or some photographic method. The outstanding characteristics of the movement may be observed, however, without the use of these refined methods. In fact, Erdmann and Dodge, who were the pioneers in the recent study of the eye movements in reading, merely observed the eye through a telescope. Instead of using a telescope we may observe the eye

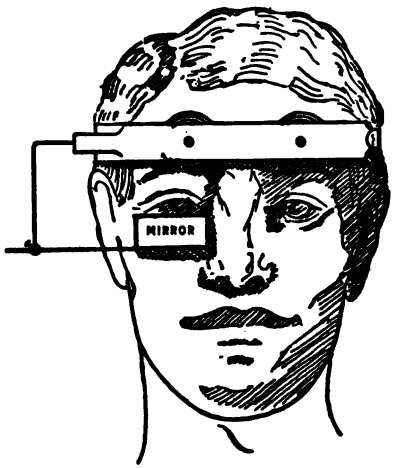

FIG. 6. MIRROR FOR OBSERVING EYE MOVEMENTS

movements in a mirror from behind the subject, as is shown in Figure 6, and thus facilitate observation by getting close to the eye which is to be observed.

The mirror is set in an adjustable frame so that it may be close to the subject's eye, and at such a height that the top of the mirror is on the level with the lower edge of the pupil of the eye when the head is held erect. With this arrangement the subject can look over the mirror and read material which is held at a level with the eye, and at the same time the experimenter can see enough of the eye to observe its movements. The subject should look toward the window, or other source of light, and the text which is to be read should be placed about on the level of the eye. It requires a little practice to catch the small and rapid eye movements, and the method is at best a means to an approximate count of the movements which are made in reading each line of print. The subject should begin at a known place on the page, and look from the left to the right margin before beginning to read, for the purpose of giving a warning signal to the experimenter. The speed of reading should be measured by means of a stop-watch in the hand of the subject. The experimenter should, without taking his eyes from the eye of the subject, make note with pencil and paper of the number of fixations made in reading each line. A frequent source of error is to count the eye movements, instead of the fixations. When this is done, either the return

sweep must be counted or 1 must be added to the count for each line. The subject should read silently and continuously.

The number of pauses to a line, and the average number of words to a pause, should be calculated; first for the same sort of subject-matter, but for different lengths of line and different sizes of print. For this purpose there are first provided two texts, the subject-matter of which is printed in 11-point type; the first, No. 1, having a length of line of 24 ems, and the other, No. 2, of 12 ems. In order to study the effect of the size of type on the eye movements, a third text, having a length of line of 24 ems and printed in 7-point type, is provided for comparison with the first specimen. In order to test the effect of the character of the subject-matter upon the eye movements, a fourth specimen, No. 4, is provided, having the same type and length of line as specimen 1, but having narrative as subject-matter. Finally, to test the speed of reading upon eye movements, a fifth specimen, No. 5, similar to specimen 1, in type, length of line, and subject-matter is provided, which is to be read as rapidly as possible. All of these texts are reproduced in the Appendix, which see.

Treatment of results. Each individual should calculate the average number of pauses per line and per unit length of line; the average number of words per line, and the average number of words perceived during one reading pause for each of the five texts. The

TABLE IX. RESULTS FROM THE STUDY OF READING PAUSES

TEXT I

Individual	*No. pauses per line*	*Ave. no. pauses per em*	*Ave. no. words per line*	*Ave. no. words per pause*	*Ave. no. pauses per second*	*Ave. no. words per second*
1.....	4.88	.20	10.8	2.2	2.1	4.81
2.....	2.89	.12	10.0	3.52	1.51	5.31
3.....	4.64	.19	11.2	2.41	1.08	2.45
4.....	2.64	.11	11.3	4.17	1.84	7.68
5.....	3.5	.14	11.0	3.4	1.17	3.67
6.....	5.0	.20	11.3	2.3	2.78	6.28
7.....	2.37	.10	10.0	4.2	2.0	8.41
8.....	3.8	.15	11.3	3.4	1.82	5.91
9.....	5.1	.21	11.3	2.2	2.0	4.4
10.....	5.7	.24	11.3	2.0	1.50	3.0
11.....	3.97	.16	11.0	2.77	1.82	5.06
12.....	7.07	.29	11.2	2.43	2.87	4.54
13.....	4.6	.19	11.2	2.43	2.0	4.32
14.....	3.4	.14	11.0	3.05	2.35	7.19
Average.....	4.25	.17	11.0	2.81	1.92	5.21

TABLE IX (*continued*)

TEXT II

Individual	*No. pauses per line*	*Ave. no. pauses per em*	*Ave. no. words per line*	*Ave. no. words per pause*	*Ave. no. pauses per second*	*Ave. no. words per second*
1.....	2.94	.24	5.08	1.7	2.7	4.7
2.....	1.09	.09	5.0	4.61	1.27	5.83
3.....	3.9	.32	5.1	1.30	1.82	2.38
4.....	1.17	.09	4.91	4.19	1.95	8.19
5.....	2.0	.16	5.0	2.50	1.27	3.18
6.....	2.7	.22	4.8	1.8	3.15	5.6
7.....	.8	.07	5.0	6.3	1.3	8.33
8.....	2.4	.20	5.0	2.1	2.62	5.44
9.....	3.0	.25	4.8	1.6	2.7	4.3
10.....	3.1	.26	5.0	1.6	1.6	2.5
11.....	2.05	.17	5.0	2.43	2.18	5.3
12.....	3.37	.28	5.1	1.48	2.12	3.88
13.....	3.0	.25	5.08	1.69	2.86	4.94
14.....	1.94	.16	4.91	2.53	3.22	8.15
Average.....	2.39	.20	4.98	2.56	2.23	5.05

TABLE IX (*continued*)

TEXT III

Individual	*No. pauses per line*	*Ave. no. pauses per em*	*Ave. no. words per line*	*Ave. no. words per pause*	*Ave. no. pauses per second*	*Ave. no. words per second*
1.....	6.34	.26	15.5	2.4	2.6	6.4
2.....	4.49	.19	16.7	3.72	1.76	6.53
3.....	7.09	.29	14.9	2.6	1.32	2.78
4.....	3.11	.13	15.3	4.56	1.8	8.22
5.....	4.5	.20	15.0	3.33	1.11	3. 7
6.....	5.83	.24	15.0	2.57	3.12	8.06
7.....	3.41	.14	16.7	4.9	2.2	10.9
8.....	3.72	.15	14.7	4.0	1.3	5.13
9.....	6.4	.27	15.0	2.30	1.9	4.3
10.....	6.4	.27	14.9	1.85	1.11	2.7
11.....	5.58	.23	15.0	2.68	2.14	5.75
12.....	8.04	.33	14.9	1.85	2.3	4.3
13.....	8.37	.34	15.4	1.84	2.5	4.61
14.....	4.63	.19	15.3	3.29	2.4	7.92
Average.....	5.56	.23	15.3	3.03	1.97	5.81

TABLE IX (*continued*)

TEXT IV

Individual	*No. pauses per line*	*Ave. no. pauses per em*	*Ave. no. words per line*	*Ave. no. words per pause*	*Ave. no. pauses per second*	*Ave. no. words per second*
1.....	4.91	.20	12.4	2.5	2.9	7.25
2.....	3.12	.13	12.0	3.85	1.75	6.74
3.....	5.06	.21	12.8	2.53	1.6	4.07
4.....	1.88	.08	12.3	6.56	1.53	10.07
5.....	3.5	.14	12.0	3.42	1.09	3.71
6.....	4.33	.18	12.3	2.84	3.03	8.61
7.....	2.48	.10	12.0	4.8	2.35	11.4
8.....	3.03	.12	12.5	4.1	2.1	8.7
9.....	5.3	.22	12.3	2.3	2.4	5.5
10.....	5.1	.21	12.5	2.4	1.9	4.6
11.....	3.88	.16	12.0	3.09	2.61	8.04
12..	6.87	.28	12.8	1.86	2.67	4.97
13.....	5.28	.22	12.4	2.16	2.66	5.98
14.....	3.11	.13	12.4	3.97	2.57	12.1
Average.....	4.13	.17	12.3	3.31	2.23	7.27

TABLE IX (*continued*)

TEXT V

Individual	*No. pauses per line*	*Ave. no. pauses per em*	*Ave. no. words per line*	*Ave. no. words per pause*	*Ave. no. pauses per second*	*Ave. no. words per second*
1.....	4.31	.18	10.7	2.4	2.5	6.2
2.....	3.4	.13	10.3	3.29	1.67	5.47
3.....	5.44	.22	10.7	1.96	1.42	2.79
4.....	2.05	.08	10.6	5.15	2.0	10.3
5.....	3.57	.13	11.0	3.59	1.5	5.38
6.....	3.46	.14	11.3	3.26	2.95	9.64
7.....	2.2	.09	10.3	4.7	2.2	10.3
8.....	3.09	.13	10.8	3.4	2.16	7.4
9.....	5.4	.22	11.3	2.1	3.6	7.5
10.....	4.2	.18	10.6	2.5	2.2	5.7
11.....	3.82	.16	11.0	2.87	3.52	10.13
12.....	5.51	.23	10.7	1.81	2.57	4.66
13.....	5.0	.20	10.6	2.13	2.62	5.05
14.....	3.6	.15	10.6	2.89	2.38	6.82
Average.....	3.93	.16	10.7	3.0	2.38	6.96

average number of pauses made per second and the number of words read per second should also be calculated. Note should also be made of the ease or difficulty, comfort or discomfort, and attractiveness or unattractiveness of the various texts. The general report should include a table in which these facts are brought together in such a way that individual differences and averages shall appear. These results should then be interpreted.

Results of the experiment. A summary of the numerical results from one section of fourteen individuals in Experiment No. 9 is presented in Table IX. A word should be said regarding the degree of accuracy of these results to enable one to discriminate between those conclusions which are justified and those which are not. In the first place, the count of the number of pauses per line, which is the basis of all the formulation of results, is probably in all cases, and clearly in some, inaccurate. Note, for example, the record of eight tenths of a pause per line for Individual 7, in Series II. Though the lines in this series were short, it is contrary to all the evidence which has been obtained by an accurate method of recording to suppose that a person can read more than a line per pause. This, and other low records, is probably due to two errors: first, the failure to catch some of the eye movements; and second, counting the movements within a line instead of the pauses, resulting in two pauses being counted as one. The results then are, in general, lower than they

should be in pauses per line, but we cannot tell how much. We cannot from these results, then, draw any definite conclusions regarding the absolute number of pauses per line or any of the facts which are derived from them.

A further difficulty is due to the variability in accuracy among the different observers. It is certain that some fell into the error which has been mentioned of counting movements instead of pauses, and there are undoubtedly differences in accuracy besides this. This makes it impossible to make any certain statements about individual differences on the basis on these data, except in reference to the relation of the different series to one another. Furthermore, there are some inaccuracies in the individual calculations themselves, as is shown by the difference in the calculation of the number of words per line, and by the failure of some members to check which should. For instance, the number of words per second should be the product of the number of words per pause and the number of pauses per second, but it is not so in all cases. This is a type of inaccuracy which ought not to occur.

Notwithstanding these errors, there is a fair degree of reliability in the comparison of the results obtained with the successive texts; since some of the errors are fairly constant, and the others, in the average results of a group, counterbalance one another. One other possible error which would affect the comparison of earlier series with later ones is an increase in skill in the

observers, enabling them to detect more fixations as they become more practiced. This would result in relatively too many fixations or pauses in the later series. This does not seem to be true to an appreciable extent, however, since the pauses per em, or unit length of line, are fewer in the last series than in the first. We may hold that they should be still fewer than they are in comparison, but it seems likely that this source of error is not serious. We may then proceed to compare the data regarding eye behavior for the group under the conditions of the five series.

Take first the final product of the various factors, the rapidity of reading as expressed in terms of words read per second. Of the four texts which were read without any especial attention to speed, the fiction is read most rapidly by each individual, considerably so by most. On the average it is read more rapidly than the scientific text, No. 5, which is read rapidly intentionally, though there is not much difference in speed between reading fiction and intentionally rapid reading of scientific material. Of the three selections which differ in length of line or size of type, but are alike in subject-matter, that which is printed in small type is read most rapidly, on the average, and by eight out of the fourteen individuals. Between Texts I and II there is not much difference, the average being slightly in favor of the longer line.

What now are the factors in these differences in the rate of reading? Compare first fiction with the other

materials. When we examine the data in detail we discover that the more rapid reading of this text is partly due to a fact which decreases its significance, namely to the fact that the words are shorter, as is indicated by the larger number in a line as compared with the other texts of the same type and length of line. We should then expect more words to be read per second. The number of words per line also affects the number of words read per pause. The number of pauses per line is practically the same as in reading the first text, and hence if the words were of the same length the number of words read per pause would be the same. There is no superiority manifested, then, in the span of attention in reading fiction material. There is a slight superiority, however, in the frequency of the pauses themselves, as indicated by greater number of pauses per second. If this should be confirmed by more careful investigation it would indicate that ease of apprehension serves to lessen the duration of eye pauses rather than to increase their scope.

If we examine the data for Text V, for intentionally rapid reading, we see that the gain was made by both an increase in the scope of apprehension at each pause (decrease in the number of pauses per line or per em) and a decrease in the duration of the pauses (increase in the number of pauses per second). If we assume that the increase in the rapidity of reading of this text is due to a greater output of mental energy, it appears that such an increased output expresses itself both in increased scope and in decreased duration.

It only remains to notice the effect of length of line and type. The shorter line appears to result in a greater number of pauses per unit distance, but this is partly counterbalanced by somewhat lessened duration of the pauses. The greater number of pauses seems to be easily explicable by the fact that at the end of the line there is likely to be waste, due to the fact that the amount left over from the next to the last pause is not enough to supply the number of words for a normal fixation, but is enough to necessitate an additional one. If we multiply the number of ends of lines we obviously multiply the number of chances for this condition. These results and this explanation should be compared with Dearborn's discussion of the length of line and its effect upon perception in reading.

The finer type seems to allow somewhat greater scope of fixation, but the number of fixations per second does not increase.

Extension of the experiment. Two ways readily suggest themselves in which this experiment may be amplified or extended. In the first place the results may be gained by a more accurate method. This necessitates the use of some sort of accurate recording device. The two general methods which have been used are the attachment of a lever to the eye by placing a very light cup on the cornea and connecting it with the lever by a fine thread. This method was used by Huey. The other refinement of method uses photography. Dodge and Dearborn photographed the bright spot on

a falling plate. The kinetoscopic method, used by Judd in studing other eye movements, is also applicable in the study of eye movements in reading. The photographic method has entirely superseded the mechanical lever method on account of its safety, and the fact that it interferes less with the natural eye movements.

Any of these refined methods require somewhat elaborate apparatus and the mastery of a moderate degree of mechanical technique. This is an illustration of the fact that, in the laboratory investigation of psychological and educational problems, the ability to devise and manipulate apparatus of a suitable sort and of a sufficient degree of delicacy is often essential. If a student is interested in specialization in educational psychology, and the laboratory offers the requisite facilities, this experiment could well be extended by taking some photographs of eye movements in reading.

The other mode of extension of this experiment is to carry further the method of observation. Other texts may be used to compare a variety of kinds of subject-matter. The method may be refined by having one observer go through a period of training in observation, and then observe the eye movements of a number of the other students. This will give some check upon the variability among the various observers.

QUESTIONS AND TOPICS FOR DISCUSSION

1. Describe the process of perception in reading so far as the character of the eye movements gives evidence concerning it.
2. What evidence is there from the experiment as to:
   a. The influence of external conditions on the eye movements?
   b. The influence of the apprehension of meaning on the eye movements?
3. How far does it seem likely that development of eye-movement habits is an important factor in learning to read?
4. Consider the question of most favorable size of type, length of line, and arrangement of line in printing.

REFERENCES

Dearborn, W. F. *Psychology of Reading.*

Huey, E. B. *Psychology and Pedagogy of Reading.*

Judd, C. H., McAllister, C. N., *and* Steele, W. M. "Introduction to a Study of Eye Movements by Means of Kinetoscope Photographs"; in *Psychological Review, Monograph Supplement* (1905), vol. 7, pp. 1–16.

Experiment No. 10

STUDY OF THE PERCEPTUAL PROCESS IN READING BY THE TACHISTOSCOPIC (OR BRIEF EXPOSURE) METHOD

Problem. In reading, as in other products of perceptual development, expertness is reached by the recognition of increasingly complex objects. The character of the eye movements which were studied in the previous experiment indicates that in adult reading numbers of letters and even words are grouped or fused in the recognition which occupies a reading pause. In this experiment this fusion is to be studied by comparing various cases in which it exists in different degrees.

Material and Method. Since a reading pause consists in a very brief fixation of the eye, we may artificially produce reading pauses by exposing reading matter for a brief interval of time, and thus study the successive reading acts in isolation. In particular we are able to determine how much of different kinds of material may be recognized in each of several successive exposures, and thus how the recognition may be built up. This method may be used to study the differences in fusion in the recognition of different kinds of material, on the assumption that the greater the fusion between the elements of the perception the greater will be the amount which can be recognized in a given exposure, or the fewer will be the number of exposures necessary to recognize the whole.

The apparatus is one of a number which have been devised to expose objects to view for a brief time. Because of the fact that the exposure is made by a falling screen, the apparatus is called a fall tachistoscope. An opening in the screen exposes the stimulus card for a length of time depending on the size of the opening and the height from which the screen drops. Any of the commonly used tachistoscopes will serve the purpose. A small instrument in which the screen is operated by a spring instead of by gravity, devised by Professor Dearborn of Harvard, is especially to be recommended because of its compactness and slight noise.

In making each exposure the experimenter should make sure that the subject is in a favorable position and ready to pay attention. He should then give a warning signal, followed in about one second by the exposure. He should be careful to keep the interval between the warning signal and the exposure as constant as possible. The subject should write down what he was able to recognize after each exposure, and should not give his reply aloud to the experimenter. The experimenter should not look at the face of the cards. The exposures of each card should continue until the subject is satisfied, but he should not be told whether or not his recognition is correct. The next card may then be shown. The subject should make introspective notes.

We shall first compare the amount of fusion which

exists in the recognition of groups of digits and groups of the same number of letters in short words. The lists are given in the Appendix, which see.

The second comparison is between groups of nonsense syllables and groups of short words arranged in a sentence, and containing approximately the same number of letters.

The third comparison is between the recognition of familiar and unfamiliar words.

The fourth group of words is for the purpose of studying the "proof reader's fallacy" — that is, the neglect of errors in words. The existence of this neglect is an evidence of fusion or recognition of the group as a whole, rather than of each unit for itself. The subject should not know which words contain errors, nor should he be required to detect them or make special effort to recognize details.

Treatment of results. The results may be made comparable by dividing in each case the number of objects (letters or digits) exposed by the number of exposures necessary to recognize them, to give what we may for convenience call the average number of objects recognized per exposure. The larger this number the greater we may assume the fusion among the objects to have been. The individual reports should include a calculation of this number of objects recognized per exposure for the different classes of stimuli, with some interpretation of the result. The general report should generalize the individual results and determine individual differences.

TABLE X. THE AVERAGE NUMBER OF LETTERS OR DIGITS RECOGNIZED PER EXPOSURE

(Based on the total number of letters or digits exposed, divided by the number of exposures necessary to recognize them)

Individual	*Series*							
	IA Digits	*IB Short Words*	*IIA Nonsense syllables*	*IIB Short sentences*	*IIIA Unfamiliar words*	*IIIB Familiar words*	*IV Words, including misspellings*	*Average*
A.....	1.5	4.3	2.0	4.3	1.2	5.6	3.0	3.1
B.....	1.2	5.0	2.1	4.4	3.4	7.0	3.6	3.8
C.....	.9	5.2	1.1	4.3	.7	12.0	4.5	4.1
D.....	1.5	6.0	2.1	5.9	1.8	7.0	5.5	4.3
E.....	1.5	4.5	2.9	6.3	1.2	10.0	5.4	4.5
F.....	1.2	4.0	2.0	6.5	1.8	14.0	4.3	4.8
G.....	1.5	6.0	2.9	7.6	2.6	10.5	5.0	5.2
H.....	2.6	5.5	2.4	7.2	1.6	12.0	5.5	5.3
I.....	2.7	4.7	1.2	7.2	6.7	14.0	6.3	5.8
J.....	1.9	6.0	2.3	8.3	3.9	14.0	5.4	5.9
K.....	2.4	5.0	2.7	6.9	2.6	14.0	8.5	6.0
L.....	1.5	5.1	2.0	7.6	3.9	14.0	8.5	6.1
M.....	1.9	5.0	3.6	10.8	3.4	14.0	7.7	6.6
N.....	1.8	5.8	3.8	10.1	3.3	14.0	8.4	6.7
O.....	2.0	6.0	3.5	8.2	6.5	14.0	8.5	7.0
P.....	2.0	6.0	3.7	13.0	4.3	14.0	8.0	7.3
Q.....	1.7	5.7	3.0	15.0	8.7	13.0	7.3	7.8
R.....	2.0	6.0	3.1	9.6	13.0	14.0	7.3	7.9
Average	1.7	5.3	2.6	8.0	3.9	12.1	6.3	5.7

Results of the experiment. The summary of the results of a group of eighteen individuals is given in Table X. The main facts are evident without the ne-

cessity of a minute analysis. A comparison of both the individual and the average results of the various series or kinds of stimuli makes clear the wide difference in the range of objects which can be recognized at a glance, or which can be apprehended simultaneously, according to the degree to which the elements are organized. These results do not in every case indicate the limit of simultaneous apprehension for a particular kind of stimulus, since the groups (words or sentences) were not in all cases large enough to reach the limit of ability of some of the individuals. It must be remembered also that most of the individuals were unpracticed in tachistoscopic work.

Wide individual differences are also brought out by the results, though these are to be somewhat discounted by differences in procedure of the various experimenters. In general, the individual differences are similar in the various series, indicating that a similar factor is present in the recognition of the various kinds of objects. These differences may be subjected to further analysis by turning the individual scores into percentages of the average, and noting the percentage differences between the extremes in each series. The correlations between the standing in the various series may also be worked out. One of the graphic methods, to be described in connection with Experiment No. 16, would be useful for this purpose.[1] There is no evidence

[1] See the chapter in Whipple for references to Messmer, Meumann, and others who have made a distinction between objective and subjective observers.

in these results to support the view that there are clearly separated types, however we may interpret the individual differences which appear.

Extension of the experiment. It is a profitable exercise to identify the individual subjects in the various experiments, and determine how far individual differences in certain of those which are similar show correlation. The results of this experiment may thus be correlated with the results of Experiment No. 12, "Apprehension of Number."

The experiment may be extended by using still other kinds of objects, such as those of the spot pattern test (see Whipple for description). Children's recognition of words may also be studied and compared with their reading ability in general. This has proven to be a valuable diagnostic test.

QUESTIONS AND TOPICS FOR DISCUSSION

1. Is there any resemblance between the perceptual process in reading and in the apprehension of the figures studied in Experiment No. 2?
2. Argue for or against the proposition that adult or developed recognition of words, or groups of words, implies previous analysis and synthesis of the elements of which it is composed. Because the adult does not notice all the details in his rapid recognition of a word, is his recognition like that of the child who is in the first stages of reading?
3. Why are groups of digits not recognized as are groups of letters? What is present in the one and not in the other?
4. What individual differences are there with reference to the matter referred to in question 3 (the recognition of the elements of a word)?
5. Is there evidence of distinct types? If not what is the nature of the differences?
6. Are there disadvantages in very narrow or very broad scope of attention in word recognition? What would be the effect of the two on reading?
7. Does the difference in the fusion of different kinds of words indicate anything with regard to the possibility of increasing the scope of attention by training?

REFERENCES

Same as for Experiment No. 7, and in addition:

Freeman, F. N. *Psychology of the Common Branches*, chap. 4. (Also on the other school subjects.)

Judd, C. H. *Genetic Psychology for Teachers*, chap. VIII.

Whipple, G. M. *Manual of Mental and Physical Tests*, vol. I, chap. VII.

Experiment No. 11

Efficiency of Reading

Problem. The practical application of the knowledge of the psychological nature of reading may be made by studying the conditions which determine the efficiency of reading. There are at least three elements to be taken into account in a complete determination of the efficiency of reading; namely, (1) the rate of reading, (2) the amount which is retained, and (3) the extent to which what is read suggests relevant trains of thought. The first two elements may be regarded as concerning efficiency of assimilation of what is read, and the third element as related to the ability to use what has been read. Previous experiments have dealt with the first two elements. On this account, and because these are the elements most easily measured, they are made the subject of this experiment. Attention is called to the fact, however, that final conclusions cannot be drawn until the third element also is studied.

Material and method. In the present experiment, measurements will be made of the speed of reading and of the amount retained in reading two halves from a passage to be selected by the instructor. The passage should be ten pages or more in length and of uniform subject-matter. A division should be made in the middle of the passage. The subject should first read the

first half of the passage at his ordinary rate, keeping the time with a stop-watch. He should then immediately write what he can remember of it, trying to reproduce the ideas, but not necessarily the exact words. Let him then continue to read the passage, now reading as rapidly as possible consistent with a clear grasp of the meaning. When he has finished, he should measure the time required to read it and write what he remembers of it.

Treatment of results. The individual reports should show clearly — first, how many words per second were read in each passage; and, secondly, what proportion of each passage was remembered. There are two methods of determining how much is remembered of a passage. We may designate these the verbal method and the idea method. Each individual in making up his report may use the verbal method. An exact form of the verbal method is to count the number of the particular words which were used in the original which are also to be found in the reproduction. The simpler procedure which may be used in this experiment consists in counting the number of words of the reproduction which express ideas occurring in the original, and finding the ratio of their number to the number of words in the original. This is of course only a rough approximation, since the same idea may be expressed by one person in a few words and by another person in many. For the comparison of the two reproductions by the same person, however, it may serve.

For the comparison of the amount which is reproduced by the different individuals, which is the concern of the person who makes the general report, the idea method is fairer. By this method the original passage is divided into thought units.[1] The thought units may be made more or less comprehensive, and it is therefore desirable that one person grade all the papers. Hence this method is recommended for the general report only. The one essential is that the principle of division into units be the same throughout.

A third method which is useful in some cases is to measure the correctness of answers to questions in the passage read.

The problems which should be attacked by means of the data which are furnished by this experiment are in the main two: (1) What is the relation between the speed of reading and the amounts which may be reproduced? and (2) Through what modifications of the mental process is the speed of reading increased? Each individual may gain light on these questions by analyzing objective and introspective results from his own experiments. The general report should contain a summary of such facts as are brought out in the individual reports and should, in addition, study the correlation between speed and reproduction when different individuals are compared.

To give an exact measure of such correlation re-

[1] Cf. C. H. Judd, "Reading Tests"; *Elementary School Teacher* (1914), vol. 14, p. 371.

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[1] Cf. C. H. Judd, "Reading Tests"; *Elementary School Teacher* (1914), vol. 14, p. 371.

TABLE XII (*continued*)

Relation between rapidity of reading and number of words reproduced in the first reading						*Relation between rapidity of reading and number of words reproduced in the second reading*					
E			*F*			*G*			*H*		
Individual	*Rapidity of first reading in order of rank*	*Words reproduced in first reading in same order*	*Individual*	*Words reproduced in first reading in order of rank*	*Rapidity of first reading in same order*	*Individual*	*Rapidity of second reading in order of rank*	*Words reproduced in second reading in same order*	*Individual*	*Words reproduced in second reading in order of rank*	*Rapidity of second reading in same order*
1	6.9	500	1	710	3.7	1	9.3	156	1	774	6.0
2	5.5	307	2	705	3.3	2	7.0	120	2	772	4.9
3	5.5	326	3	583	2.7	3	6.0	774	3	675	4.5
4	5.3	359	4	556	3.2	4	5.8	413	4	642	3.4
5	4.7	235	5	500	2.2	5	5.7	338	5	615	3.7
Average	5.6	345		611	3.0		6.8	360		696	4.5
6	4.7	425	6	500	6.9	6	5.2	513	6	600	4.8
7	3.9	225	7	486	2.7	7	4.9	772	7	513	5.2
8	3.7	710	8	425	4.7	8	4.9	338	8	484	4.9
9	3.5	187	9	396	2.8	9	4.9	484	9	413	5.8
10	3.3	705	10	393	2.9	10	4.8	600	10	346	3.7
11	3.2	556	11	370	2.9	11	4.5	675	11	340	4.1
Average	3.7	468		428	3.8		4.9	564		449	4.8
12	2.9	270	12	359	5.3	12	4.2	234	12	338	4.9
13	2.9	251	13	352	2.7	13	4.1	340	13	338	5.7
14	2.9	270	14	326	5.5	14	3.7	325	14	325	3.7
15	2.9	370	15	307	5.5	15	3.7	291	15	325	3.7
16	2.9	393	16	270	2.9	16	3.7	346	16	291	3.7
Average	2.9	311		323	4.3		3.9	307		322	4.3
17	2.8	398	17	270	2.9	17	3.7	325	17	248	3.6
18	2.7	486	18	251	2.9	18	3.7	615	18	234	4.2
19	2.7	352	19	235	4.7	19	3.6	248	19	174	3.4
20	2.7	583	20	225	3.9	20	3.4	642	20	156	9.3
21	2.2	500	21	187	3.5	21	3.4	174	21	120	7.0
Average	2.6	464		234	3.6		3.6	401		186	5.5
Final average	3.7	400		400	3.7		4.8	415		415	4.8
Median	3.2	370		370	3.2		4.5	340		340	4.5

TABLE XII (*continued*)

Relation between increase in rapidity and increase or decrease in words and ideas reproduced					*Relation between rate of reading, gain or loss in rate and gain or loss in reproduction*				
I					*J*				
Individual	*Increase in rapidity in order of rank*	*Increase or decrease in words reproduced in same order*	*Increase or decrease in ideas reproduced in same order*	*Rapidity of first reading*	*Individual (numbered as in Section I)*	*Rapidity of first reading*	*Increase in rapidity*	*Increase in words reproduced*	*Increase in ideas reproduced*
1	5.4	− 69	− 4	3.9	21.	6.9	−2.1	100	2
2	3.3	288	6	2.7	5.	5.5	1.5	−206	− 3
3	2.8	− 55	2	2.9	20.	5.5	−1.4	33	− 2
4	2.1	− 88	4	2.8	19.	5.3	−0.1	154	−10
5	1.5	−206	− 3	5.5	17.	4.7	.2	− 12	− 5
Average	3.0	9	1	3.6		5.6	− .4	14	− 4
6	1.2	62	− 7	3.7	9.	4.7	1.1	103	6
7	1.2	− 30	− 1	3.3	1.	3.9	5.4	− 69	− 4
8	1.2	142	5	2.2	6.	3.7	1.2	− 62	− 7
9	1.1	− 12	− 5	4.7	18.	3.5	−0.1	− 13	10
10	1.0	−322	−10	3.2	7.	3.3	−1.2	− 30	− 1
11	1.0	32	16	2.7	10.	3.2	1.0	−322	−10
Average	1.1	− 21	− 0.33	3.3		3.7	1.6	− 47	− 1
12	.9	−104	− 2	2.7	3.	2.9	2.8	− 55	2
13	.8	55	6	2.9	13.	2.9	.8	55	6
14	.8	40	....	2.9	14.	2.9	.8	40	....
15	.8	76	1	2.9	15.	2.9	.8	76	1
16	.8	− 45	1	2.9	16.	2.9	.8	− 45	1
Average	.8	4	1	2.9		2.9	1.2	14	2.5
17	.2	103	6	4.7	4.	2.8	2.1	88	4
18	− .1	− 13	10	3.5	2.	2.7	3.3	288	6
19	− .1	154	−10	5.3	11.	2.7	1.0	32	16
20	−1.4	33	− 2	5.5	12.	2.7	.9	−104	− 2
21	−2.1	100	2	6.9	8.	2.2	1.2	142	5
Average	− .7	75	1	5.2		2.6	1.7	89	6
Final average	1.2	15	− .71	3.7		3.7	1.1	15	.75
Median	1.0	33	1	3.2		3.2	1.0	33	1

Results of the experiment. The summary results of this experiment are presented in Table XI. These results have been reformulated to facilitate comparison in Table XII. The data are presented in the general table in order that one may follow the record of any individual throughout the table. In Table XII the individuals are rearranged in each section so as to put the scores into regularly descending order.

The first comparison to be made is between the rapidity of reading in the first and second halves of the selections. The increase in rapidity as a result of the effort to read rapidly is large for the class as a whole, being 27 per cent if we use the averages, and 41 per cent if we use the medians.

The more particular question which is presented by our results concerns the relationship between the standing of the individual subjects in rapidity of reading of the two halves of the selections. Are those who read rapidly in the reading at the ordinary rate the most rapid readers when they try to increase the speed? This is the type of problem which involves the calculation of correlation. If the order of the scores in the two series is the same, or if there is any more correspondence than would be present by pure chance, the correlation is positive. If the order is reversed, partly or wholly, the correlation is negative. The more precise methods of calculating or representing the degree of correlation will be illustrated in Experiment No. 16. We shall be content here with the arrangement of the

data in such a way as to facilitate an inspection of them, and the detection of the outstanding facts of correlation.

Sections A and B present the data regarding the correlation between the speed of reading of the class in the two parts of the selection. In Section A the individuals are arranged in the order of the rapidity with which they read the first half, and in Section B in the order of rapidity of reading the second half. As a very rough method of estimating the correlation the series are divided into four approximately equal groups, and the average is given for each group. The averages, of course, decrease as one goes down the column in the left-hand column in each section. If the averages of the right-hand column also decrease in the same order there is probably some correlation. Inspection of the individual scores makes possible more detailed statements.

It appears that there is some correlation between the rapidity of the first and second readings. In general, those who read rapidly in the first part read rapidly also in the second part. Those who read most rapidly in the second part, however, were not as rapid in the first part as were the second group. Those who read most rapidly the first time apparently were reading nearly at their maximum and did not increase their speed (with one exception), but actually fell off in the second reading. All the other groups, as appears from Section C, increased their speed materially. But while

some of the slow readers in the first half of the test read rapidly in the second half, those who were slow when they read under pressure were in the main slow when they read at their natural rate. We may conclude from these facts that those who read most rapidly in the test for natural reading were reading about as fast as they could. Some of those who read more slowly were actually capable of more rapid reading than the most rapid readers in the first test; and some of those who were toward the bottom of the class in the first test ranked in the top quarter in the second. Some of the slow readers in the first test, however, while capable of some increase in speed, remained at the bottom; and very rarely did a rapid reader in the first test fall toward the bottom in the second.

Sections C and D indicate that the slower readers in the first test, while they in general remained below the rapid readers when they intentionally speeded up, yet gained more, absolutely, and very much more relatively, than their rapid companions. These facts taken together indicate that, so far as a single test can be relied upon, the slow readers were slow partly because of some native or deep-seated acquired difference, but that the difference was in most cases greater than necessary since it could be overcome by a little effort.

From a study of Sections E to H, which show the relationship between rapidity of reading and the amount which is reproduced it appears that there is a diversity of cases. If we examine Sections E and G we

see that some rapid readers remember a large amount of what they read — for example, No. 1 in Section E and No. 3 in Section G. It also appears from the same sections that some of the slow readers — as Nos. 18, 20, and 21 in Section E, and Nos. 18 and 20 in Section G — reproduce a large amount. In the same manner it may be shown that there are both fast readers and slow readers who remembered little of what they read. Columns F and H show the converse of these facts.

While there are individual cases which show a correspondence between speed and reproduction, and other cases in which there is a wide discrepancy between the two elements, there may still be in general a positive or a negative correlation. If there is a large amount of correlation, either positive or negative, it should be indicated by the averages of the groups in the second column of each section. There is clearly no strongly marked positive correlation, but, on the other hand, some negative correlation. In each case the five most rapid readers reproduce less than the five slowest, and the five who reproduce most read more slowly than the five who reproduce least.

These facts may be summarized in the following statements: —

Some individuals read rapidly without sacrifice to comprehension, while others attain speed at the expense of comprehension. The latter are slightly more numerous than the former.

Some individuals read slowly without a correspond-

first half of the passage at his ordinary rate, keeping the time with a stop-watch. He should then immediately write what he can remember of it, trying to reproduce the ideas, but not necessarily the exact words. Let him then continue to read the passage, now reading as rapidly as possible consistent with a clear grasp of the meaning. When he has finished, he should measure the time required to read it and write what he remembers of it.

Treatment of results. The individual reports should show clearly — first, how many words per second were read in each passage; and, secondly, what proportion of each passage was remembered. There are two methods of determining how much is remembered of a passage. We may designate these the verbal method and the idea method. Each individual in making up his report may use the verbal method. An exact form of the verbal method is to count the number of the particular words which were used in the original which are also to be found in the reproduction. The simpler procedure which may be used in this experiment consists in counting the number of words of the reproduction which express ideas occurring in the original, and finding the ratio of their number to the number of words in the original. This is of course only a rough approximation, since the same idea may be expressed by one person in a few words and by another person in many. For the comparison of the two reproductions by the same person, however, it may serve.

For the comparison of the amount which is reproduced by the different individuals, which is the concern of the person who makes the general report, the idea method is fairer. By this method the original passage is divided into thought units.[1] The thought units may be made more or less comprehensive, and it is therefore desirable that one person grade all the papers. Hence this method is recommended for the general report only. The one essential is that the principle of division into units be the same throughout.

A third method which is useful in some cases is to measure the correctness of answers to questions in the passage read.

The problems which should be attacked by means of the data which are furnished by this experiment are in the main two: (1) What is the relation between the speed of reading and the amounts which may be reproduced? and (2) Through what modifications of the mental process is the speed of reading increased? Each individual may gain light on these questions by analyzing objective and introspective results from his own experiments. The general report should contain a summary of such facts as are brought out in the individual reports and should, in addition, study the correlation between speed and reproduction when different individuals are compared.

To give an exact measure of such correlation re-

[1] Cf. C. H. Judd, "Reading Tests"; *Elementary School Teacher* (1914), vol. 14, p. 371.

Furthermore the slow readers can increase the speed materially without loss in comprehension, or even with a gain, while an increase in speed among the rapid readers usually results in a loss in comprehension.

Extension of the experiment. These conclusions demand extension and verification through the collection of results from larger numbers. One very useful extension could be made by giving several tests with different kinds of subject-matter to the same group of individuals. A single test is never an adequate basis on which to measure the ability of an individual. It would be well to make a number of tests with a group of persons without saying anything about speed at first, in order to obtain a reliable measure of reading ability at the ordinary rate. The next step would be to give a whole series of texts to be read rapidly in order to find out the amount of improvement in speed of which the various individuals were capable, the amount of practice to bring each one up to his approximate maximum, and the final effect of the increase in rate on the comprehension of the various individuals.

A less extensive experiment than the foregoing might well be made by repeating the experiment with various kinds of subject-matter, as essays, fiction, and poetry. Another variation which usually gives very good results consists in having a limited number of individuals — even so few as one will do — carry on a practice experiment for the purpose of increasing the rate of reading.

QUESTIONS AND TOPICS FOR DISCUSSION

In addition to the specific problems mentioned above, the following questions may be discussed: —

1. What seems in your experience to be the effect of the following factors in determining the rate of reading: eye-movement habits; the amount of inner articulation used; the rapidity of apprehension of meaning; attention to word characteristics (diction, shades of meaning, sound, characteristics as used in alliteration, onomatopœia, etc.), melody, balance of sentence structure?
2. Should you say that the best speed of reading of different sorts of subject-matter, e.g. scientific prose, essays, novels, poetry, is the same? What considerations determine the best speed for these different kinds of material?
3. How may speed of reading be increased?
4. Has rapid reading any conceivable advantage beside economy of time?
5. Should speed of reading be uniform?
6. How may one strike the proper balance between speed and apprehension of meaning?
7. Propose means of improving the apprehension of meaning.

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Experiment No. 12

APPREHENSION OF NUMBER

Problem. The abstract idea of number is the outgrowth of various forms of concrete experience, and in most if not all cases it never becomes entirely independent of some sort of imagery which reflects concrete experience in visual or mimetic terms. The study of visual experiences which form the basis of number apprehension, and which exhibit it in simple and more elaborate forms, will therefore give some insight into the means by which the idea of number is developed.

There are a variety of forms of concrete experience through which the idea of number may be developed. One is counting, which consists in giving attention to a series of objects in succession, at the beginning guiding the attention by pointing, handling, objects, etc. and designating each object in the series by a number name. Another is the division of an object — a length, surface, or solid — into equal parts, and designating the sum of the parts by a number name. The third form of experience, which will constitute the basis of this experiment, consists in the simultaneous apprehension of a group of objects, and the designation of the group by a number name. What we may call the *perception* of number exists in each of these cases prior to the use of number names, and forms the basis of the idea which is represented by the verbal expression.

Our problem in this experiment is to study the effect of grouping upon number apprehension.

Material and method. The most convenient method of studying the simultaneous apprehension of a group of objects is to present the group to view for a short space of time by the brief exposure or tachistocopic method. We shall use groups of dots placed upon white cards and presented by means of the fall exposure apparatus. In order to test the effect of grouping, one series of cards contains dots arranged in a straight horizontal row, with equal spaces between them; another series contains dots arranged in irregular grouping; and the other series contains dots in certain regular forms of grouping. The stimuli used are reproduced in the Appendix, which see.

The cards of each series should be presented in irregular order, so that the subject may not be able to anticipate what the number about to be presented may be. As each card is reached in the series it should be presented once (after warning signal), and the subject should make a record of his judgment of the number of spots, of their arrangement, and any introspections he may make. Each judgment may afterward be identified and its correctness determined by labeling it with the number of the series and its number in the sequence of presentations in the series. After all the series have been presented once, they may be presented a second time, and each subject's score may be based upon the second trial. Experimenter and subject may exchange

places each time after the completion of the presentation of the whole series of cards.

Treatment of results. The numerical results of this experiment may be simply expressed. Each individual should report his judgments in the two trials upon each number of each series. For this purpose the numbers should be arranged in consecutive order. He should then determine and record the highest number of each series which was correctly judged in the second trial. Furthermore, he should classify the errors in each series and in the whole number of judgments into underestimations and overestimations, and calculate the proportion of each.

The general report should contain a table and chart based upon the percentage of correct judgments (based upon the second judgment in each case) which were passed by the class as a whole upon each stimulus card. The chart and table should exhibit a comparison of the percentage correctness of the judgments of the same numbers in the different series.

TABLE XIII. PERCENTAGE OF CORRECT JUDGMENTS FROM A GROUP OF TWENTY INDIVIDUALS UPON EACH NUMBER OF THE VARIOUS SERIES

Number	3	4	5	6	7	8	9	10	11	12	13	14	15
Series													
I....	..	80	45	40	40	35	25	..	..	..	..	..	..
II....	100	85	75	70	60	45	45	..	..	..	..	..	..
III....	..	..	85	80	80	75	60	65	55	55	..	..	..
IV....	..	90	85	85	70	45	60b	30	25	40	..	..	..
V....	..	..	..	95	75	70	100	70	60	90	55	30	45

Results of the Experiment. Table XIII and Chart V give the data for the comparison of the apprehension of the various sorts of arrangement of the dots. The facts may be most readily inspected in the chart. It is

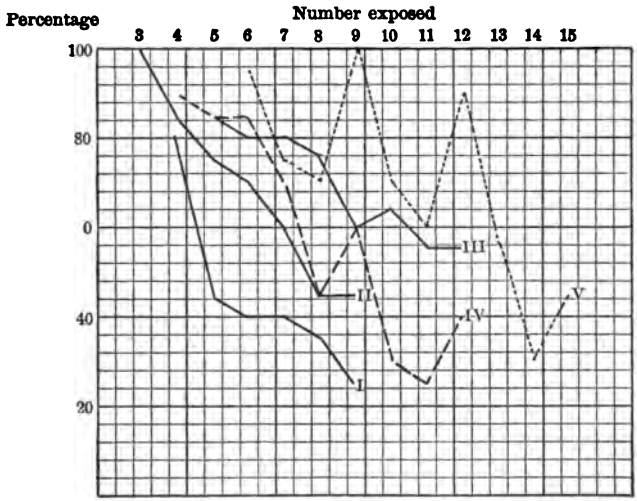

CHART V. GRAPHIC REPRESENTATION OF THE PERCENTAGE OF CORRECT JUDGMENTS GIVEN IN TABLE XIII

I. Irregular arrangement
II. Horizontal row
III. Grouping by fours
IV. Grouping by threes
V. Grouping by fives

apparent at a glance that there is a radical difference in the mode of apprehension of the dots in irregular grouping, and in grouping by fives, for instance, Series I and Series V. By comparison of the individual series and by a study of the introspections the effect of the various forms of grouping may be made out.

The significance of the results should be studied with reference to the light they throw upon the span of attention and the mode of organization which is produced by grouping. The apprehension of objects in groups is particularly significant as an indication of the nature of much of our recognition of number. Question 4 suggests one application of the facts. What are others?

TABLE XIV. PERCENTAGE OF ERRORS CONSISTING IN OVERESTIMATIONS IN THE VARIOUS NUMBERS OF THE DIFFERENT SERIES

(The numbers in italics represent the total number of errors)

Number	3	4	5	6	7	8	9	10	11	12	13	14	15
Series													
I...	..	*4*	*11*	*12*	*12*	*13*	*15*	..	..	..	..	..	..
	..	100	64	42	25	46	13	..	..	..	..	..	..
II...	*0*	*3*	*5*	*6*	*8*	*11*	*11*	..	..	..	..	..	..
	0	100	40	50	50	9	9	..	..	..	..	..	..
III...	..	..	*3*	*4*	*4*	*5*	*8*	*7*	*9*	*9*	..	..	..
	..	..	100	75	75	20	50	45	9	22	..	..	..
IV...	..	*2*	*3*	*3*	*6*	*11*	*8*	*12*	..	..	..	..	..
	..	100	100	66	83	73	38	14	14	8	..	..	..
V...	..	..	..	*1*	*5*	*6*	*0*	*6*	*8*	*2*	*9*	*14*	*11*
	..	..	..	100	100	17	0	33	75	50	9	14	18

Table XIV presents the facts regarding the relation of overestimation and underestimation in the apprehension of the various sized numbers of the different series. The table shows that in all the series the errors in the smaller numbers consist chiefly in overestimations, while in the case of the larger numbers the errors

are underestimations. What is the cause of this marked difference? Is it an evidence that an error in the apprehension of a smaller number of objects is of a different sort from an error in the apprehension of a larger number, or is it due to the same cause which in some way produces a different result under the two conditions? Introspections should be made use of in discussing this question. All the hypotheses possible should be presented, and their probability discussed.

TABLE XV. INDIVIDUAL DIFFERENCES IN PERCENTAGE OF CORRECT JUDGMENTS

Individual	*Percentage of correct judgments*	*Individual*	*Percentage of correct judgments*
A	10.0	K	67.5
B	45.0+	L	70.0+
C	45.0	M	70.0
D	47.5	N	72.5
E	55.0	O	72.5
F	57.5	P	75.0
G	62.5+	Q	75.0=
H	62.5	R	77.8+
I	65.0=	S	80.0
J	67.5	T	82.5

Table XV shows individual scores in the percentage of correct judgments made. The significance of such marked individual differences as are represented in this and other tables in these is one of the important problems of educational psychology. In such an experiment as this it is likely to occur to the student that purely sensory differences are likely to be responsible

for the wide divergence in the results, but there seems no good ground for this conclusion. This hypothesis may be tested by comparing the records of those who wear glasses with those of those who do not. There is some indication of a difference in the mode of apprehension in the difference in the percentages of over- and underestimations. In the majority of cases the total number of underestimations exceeds the overestimations, but in the case of four individuals, indicated in the table by the plus sign, the reverse is the case; and in the case of two, indicated by the equality sign, the over- and underestimations are equal in number. These divergent cases, however, are regularly distributed among those of high and low percentages of correct judgments.

It is very desirable to be able to determine the significance of such facts of individual difference as this, both for schoolroom practice and for the diagnosis of abilities in vocational guidance. For a discussion of some of the attempts which have been made in the latter sphere see Münsterberg.[1] Individual differences in the fundamental forms of number ability have been studied particularly by S. A. Courtis. See his article in the report of the New York School Inquiry.[2]

Extension of the experiment. A valuable extension

[1] Münsterberg, H., *Psychology and Industrial Efficiency*. Boston: Houghton Mifflin Co. 1913.

[2] Courtis, S. A., "Report on the Courtis Tests in Arithmetic"; in *Report of Committee on School Inquiry, City of New York* (1911–13), vol. 1, pp. 389–546.

of this experiment consists in making the experiment with children of various ages, and noting the type of recognition in which the older children and adults show most development. An attempt may also be made to determine whether individual differences among children reflect their ability in number work, or in any other phase of their school work.

QUESTIONS AND TOPICS FOR DISCUSSION

The student may judge which questions can be answered only in the general report.

1. What is the average scope of attention as measured by the number of different unorganized units which can be apprehended simultaneously? Within what limits does it vary?
2. How does grouping (subjective or objective) enable one to judge correctly a number of objects beyond the scope of attention?
3. Which do you think is more affected by education, the scope of attention or the ability to apprehend groups? (If opportunity offers, this question could well be tested.)
4. Does the experience obtained in this experiment suggest any means by which we may form the idea of numbers larger than can readily be grasped concretely? Does the decimal system suggest any analogy?
5. What possibilities exist in the procedure used in this experiment for the teaching of number?
6. Point out other kinds of experience in which the organization of the material increases the amount which can be apprehended as a unit.

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CHAPTER IV

TESTS

THERE are two senses which are important for the child's education and mental development, and in respect to which there are a considerable number of children in whom there is marked deviation from the normal; namely, vision and hearing. The purpose of these tests is the detection of serious deviations from the normal, and the rough determination of the character of the defect. The aim is not to determine with precision the amount of the defect nor to equip the student to prescribe remedies other than those which are included in the duty of the school administrator.

Experiment No. 13

Tests of Visual Defects

Problem. The defects which are to be tested in this experiment are myopia (near-sightedness), hyperopia (far-sightedness), astigmatism (lack of clear focusing of the image on the retina), and heterophoria (lack of muscular balance, which produces a tendency of the eyes to cross, squint, etc).

a. The first test is for the purpose of detecting the presence of myopia or hyperopia.

Myopia. This is usually caused by too great length of eyeball from front to back, as a result of which the image of an object at a distance is brought to a focus in front of the retina. Hyperopia is caused by the opposite fault, as a result of which the image would come to a focus back of the retina if the crystalline lens of the eye were at rest. Myopia cannot be corrected by the action of the crystalline lens, because this would necessitate that the lens become flatter than it is when at rest. The lens flattens, however, only through the contraction of a muscle which is constant in its tension, and which cannot be relaxed or tightened to suit the varying needs of accommodation; and hence there is no means of further decreasing its curvature. For this reason the defect is easily discovered by the inability of the subject to clearly distinguish objects as far away as can be seen by the normal eye, and by his

ability to see objects at a greater distance by the use of a lens which brings the light to a focus farther back; that is, a concave lens.

Hyperopia. This, on the other hand, is detected (provided the ciliary muscle which controls the crystalline lens has not been paralyzed by a drug) in a somewhat more roundabout way. After the analogy of myopia, we might assume that the far-sighted individual could not distinguish objects close by, but this assumption would be incorrect, for the thickening of the lens which is necessary to bring it to a focus upon objects near at hand is produced by the contraction of the muscle of accommodation — the ciliary muscle — and in the hyperopic eye it is only necessary that this contraction be more vigorous than in the normal eye. A further consequence of the defect is that even when the lens is accommodated for distant objects the ciliary muscle is not at rest, as in the normal eye, but must be more or less strongly contracted. It is this fact which is employed to detect hyperopia. If the normal eye is accommodated for a distant object and a convex lens is placed before the eye, producing in effect an accommodation for a point nearer by, the lens cannot adjust itself by further flattening, since it is already at rest; and the object as a consequence appears blurred. In the hyperopic eye, on the other hand, the lens is still somewhat thickened by the ciliary muscle, and this by further relaxing can compensate for the effect of the artificial lens, with the result that the object remains

clear. In a word, then, if the addition of a convex lens does not blur the vision of an object set at the maximum distance, the eye is hyperopic.

Material and method. The test consists merely in applying these general principles. In doing so, it is, of course, necessary to examine one eye at a time, and to keep the other eye covered without pressing upon it. Placing a blank disk in the trial frame, is a convenient method of doing this. The McCallie vision test cards [1] are recommended, because their order can be changed at will and only one letter is shown at a time, thus making an accurate record possible of what is and what is not correctly perceived.

Detailed directions. Require the subject to sit twenty feet from the spot where the cards lie face down upon a table. Cover one eye. Present the first card with the small letter at the top and ask the subject to name it. Record his answer, and continue with the other cards until ten have been presented, or until it becomes evident that the subject cannot read four out of five of the letters at that distance. If he has read correctly eight out of ten cards, there is no considerable myopia, and the test should be made for hyperopia by placing the convex lens (+.75) in the trial frame. If the subject can still read the smallest letters, there is evidence of hyperopia. If they appear blurred, the

[1] These cards may be purchased from Edwin Fitzgeorge, agent, Box 67, Trenton, N. J. A set for literates contains letters. Another set may be used with illiterates.

eye is approximately emmetropic — that is, neither hyperopic nor myopic.

If the subject cannot read eight out of ten of the smallest letters, the next larger letters should be prescribed; and if he fails to read these, the next larger; and so on. If he fails to read the largest letters, the distance should be reduced by two feet at a time until he can do so. The trial should be made now with the concave lens (−.75) to determine whether vision is improved thereby. If so, the eye is myopic.

The results may be conveniently recorded by means of the following formula: The acuity of vision is expressed by the ratio of the greatest distance from which a particular size of letter can be read to the greatest distance at which it can be read by a normal eye. Thus, if the letters marked forty are the smallest which the subject can read at a distance of twenty feet, his acuity is recorded as 20/40. It should further be recorded whether the eye is emmetropic, hyperopic, or myopic.

The same procedure should be gone through with the other eye.

b. The second test is for the purpose of detecting the presence of astigmatism.

Astigmatism. This defect is caused by an unequal curvature of one of the refracting media of the eye in its various meridians. The seat of the trouble is usually the cornea. As a result the rays of light from any given point will not reach a focus at a point, but those which meet the cornea in one meridian will be focused at one

point and those which meet it in another meridian will be focused at another point. The retina may be situated at the focus of one or the other of these meridians, or at a point different from either, and there are in consequence a variety of possibilities with regard to the retinal image. The common result, however, is that there is an elongation of the image in some particular direction due to the fact that the focal distance of the cornea in this direction is greater or less than that of the rest of the cornea. Any line, then, which is in any other than this direction of unequal curvature will appear blurred because of the elongation of the image in a lateral direction. In the case of a line which is parallel to the direction of unequal curvature, on the other hand, the elongations all fall within the line itself and hence do not produce blurring. The common method of detecting astigmatism, therefore, is to present a card which contains lines in various directions radiating from a center. If the lines in one direction appear distinct, while the rest are blurred, there is evidence of astigmatism. If astigmatism is detected by this means, the defect is sufficient to require correction. Oculists usually make a more exact diagnosis by means of trial cylindrical lenses and the opthalmoscope.

The test should be made as follows: Place the chart at a distance of twenty feet from the subject and test one eye at a time. If myopia or hyperopia exist, insert in the trial frame the lens which partially corrects the defect. Ask the subject whether the line in one direc-

tion appears blacker and more distinct than the others. If the answer is affirmative, the correctness of the judgment may be confirmed by turning the head so that the one eye is raised and the other lowered. The position of the distinct lines should shift correspondingly. If an affirmative answer is thus confirmed, the defect may be recorded as astigmatism in the axis of the lines which appear distinct.

c. **The third test.** This is for the purpose of detecting heterophoria, or the lack of muscular balance.

Heterophoria. This is caused by an unequal tension in the pairs of muscles which turn the eye out and in or up and down, or a combination of these two conditions. This inequality of tension may not produce an actual displacement of the line of vision of the eye, since the motive of clear vision may lead to an extra innervation of the muscle opposing the muscle which possesses undue tension. This, however, produces a condition of strain which may have serious effects upon the nervous system. The test for heterophoria is based upon the fact that if the motive for directing the eyes toward the same point is not present, the defect becomes manifest. This may be done by placing a lens or other medium before one eye so that the image in that eye is distorted and is not recognized as being produced by the object which is perceived through the other eye. The Stevens stenopaic lens[1] is recommended for this purpose, since

[1] The stenopaic lens should be tested to see whether it is accurate. If it is not, as is likely to happen, the Maddox rods may be used and

it reveals the direction and amount of displacement by a single determination. This is a convex lens of short focus covered except for a small opening in the center. When this lens is placed with the opening close to and in front of the pupil, a source of light, as a candle, is seen as a circular spot of diffused light. If the muscular balance of the eyes is normal, the image of the candle as seen through the other eye should appear in the center of this spot. If it does not, there is heterophoria.

Proceed as follows. Place the stenopaic lens before one eye. Place a lighted candle on a level with the eyes and twenty feet away. Direct the subject to close his eyes and immediately upon opening them and looking at the candle to say whether it appears in the middle of the circle of light; or if not, what its position is. Repeat the test with the other eye.

The results of the test should be recorded for each eye separately. The record should state whether there is heterophoria; and if there is, in what direction the lack of muscular balance exists.

Results of the experiment. The record of the test of a group of twenty-two individuals for visual acuity is shown in Table XVI. In most cases the record is consistent. For convenience in inspecting the table the cases in which a ratio less than 20/20 indicates a defect in acuity are underlined. In two cases there is a defect indicated in both eyes, and in five cases in one

the test made with the instrument in both the vertical and the horizontal positions.

TABLE XVI. RECORD OF THE TESTS FOR VISUAL ACUITY OF TWENTY-TWO INDIVIDUALS

Subject	Ratio		Letters recognised		Large letters recognised		Letters recognised with lenses			
							Convex		Concave	
	Right eye	Left eye	Right eye	Left eye	Right eye	Left eye	Right eye	Left eye	Right eye	Left eye
A.....	20/20	20/20	10	10	..	..	5	8 B‡	..	..
B.....	20/20	20/20	9	10	..	..	6	4 B	..	..
C.....	20/30	20/20	..	..	..	..	..	..	..	..
D.....	20/20	20/30	8	6	..	8*	10	8 B.L.	..	8
E.....	20/30	20/20	6	10	9*	..	6	5 B	10	..
F.....	20/20	20/20	10	10	..	..	0	0 B	..	..
G.....	20/20	20/20	10	10	..	..	10	10	..	..
H.....	20/30	20/30	3	3	8*	8*	not so good		6	8
I.....	20/20	20/20	8	8	..	..	6	3 B	..	..
J.....	20/20	20/20	8	9	..	..	8	10 B.R.	10	..
K.....	20/20	20/20	9	9	..	..	7	7 B	..	..
L.....	20/20	20/20	10	10	..	..	7	8 B	..	..
M.....	20/30	20/30	5	5	8*	8*	neither lens helps.			
N.....	20/20	20/20	10	10	..	..	0	0 B	..	..
O.....	20/20	20/20	10	10	..	..	9	9 B	..	..
P.....	20/30	20/20	4	10	8*	..	0	6 B	10	..
Q.....	20/20	20/20	10	8	..	..	8	9	..	..
R.....	20/20	20/20	10	8	..	..	..	B	..	..
S.....	20/20	20/20	10	10	..	..	8	6 B	..	..
T.....	20/20	20/50	8	10	..	8†	7	no data	..	..
U.....	20/20	20/20	9	8	..	..	10	10	..	..
V.....	20/20	20/20	10	10	..	..	5	5	..	..

* Second size. † Fourth size. ‡ Blurred.

eye only. Usually when eight or more of the smallest letters can be recognized with the naked eye the recognition is impaired by the use of either lens. In the case of Subjects D (R.E.), G, and U, however, the use of the convex lens either produces improvement or fails to impair vision. What does this indicate? In the case of four individuals vision was improved in one or both eyes by the concave lens. What does this indicate?

One case, that of M, appears, so far as this test can be relied upon, to be improved by neither lens. This may point to astigmatism, or some other form of defect, such as cataract or retinal defect. From reference to the next table no astigmatism is apparent, though expert examination would be necessary to render judgment on this point certain.

The record of the test in astigmatism, Table XVII, indicates a rather large proportion, 50 per cent of defective cases in this rather rough method of determination. The results of this method must be taken with considerable allowance for error in observation.

The results of heterophoria are presented not merely to illustrate the proportion of cases in which heterophoria is to be expected, but also to indicate that care is needed in interpreting the objective results. Take Subject D, for instance. He finds heterophoria in one eye and not in the other. Is this possible by the method used? The test depends on the *comparative* positions of the two eyes. Or take Subjects E, G, I, K, M, O, U, and V. They find, according to their report, esophoria in

TABLE XVII. RECORD OF THE TESTS FOR ASTIGMATISM AND HETEROPHORIA OF TWENTY-TWO INDIVIDUALS

+ indicates presence, and − absence of defect

Subject	*Astigmatism*		*Heterophoria in horizontal plane*					
	R.E.	*L.E.*	*R.E.*			*L.E.*		
			H [1]	*Es* [2]	*Ex* [3]	*H* [1]	*Es* [2]	*Ex* [3]
A.....	−	−	−	−	−	−	−	−
B.....	−	−	−	−	−	−	−	−
C.....	+	+	+	+	−	+	+	−
D.....	+	+	+	−	−	−	−	−
E.....	+	+	+	+	−	+	−	+
F.....	−	−	+	−	−	+	−	+
G.....	−	−	+	−	+	+	+	−
H.....	+	+	−	−	−	−	−	−
I.....	+	+	+	−	+	+	+	−
J.....	−	−	+	−	+	+	−	+
K.....	+	−	+	+	−	+	−	+
L.....	+	+	−	−	−	−	−	−
M.....	−	−	+	+	−	+	−	+
N.....	no data		+	−	+	+	−	−
O.....	+	+	+	+	−	+	−	+
P.....	+	−	−	−	−	−	−	−
Q.....	−	−	−	−	−	−	−	−
R.....	−	−	+	−	+	+	−	+
S.....	−	−	−	−	−	−	−	−
T.....	+	+	+	+	−	+	+	−
U.....	+	+	+	−	+	+	+	−
V.....	−	−	+	+	−	+	−	+

[1] Heterophoria. [2] Esophoria, or displacement inward.
[3] Exophoria, or displacement outward.

one eye and exophoria in the other. Is it possible to get this result by this method?

In order to answer these questions, and the further

question, — what does the displacement of the line to the right or left mean with the lens before each eye with reference to the relative position of the eyes? — the student should draw a diagram of the eyes, the source of light and the various possible positions of the image of the light and of the line.

Extensions of the experiment. Possible extensions of this experiment will be described at the end of Experiment XIV.

REFERENCES

For an account of the frequency of these defects, see G. M. Whipple, *Manual of Mental and Physical Tests*, chap. VI. For a full description of the various defects and their physiological basis, see H. Eulenberg and T. Bach, *Schulgesundheitslehre* (1900), vol. 1, pp. 748 *ff*.

For questions and discussions, see the end of the next experiment.

Experiment No. 14

Tests of Auditory Acuity

The most serious defect of hearing is the inability to hear sounds of an intensity (loudness) sufficient to be heard by the individual with normal hearing. The manner of testing auditory acuity is simple in principle, but the conduct of the test is attended with difficulties. It is not a simple matter to produce a series of sounds in regularly ascending or descending grades of intensity and of standard intensity. One means at hand is to vary the distance of the source of sound from the ear; but this method is attended with the complicating factor of reflecting walls, and ordinarily by the disturbing presence of other sounds in the neighborhood. This is the method of the watch test or the whisper test. To overcome these difficulties, the sound may be applied to the ear and its intensity varied in regular steps. This is the method of the audiometer.

A convenient general method of procedure, whatever the form of stimulus which is used, is a combination of the method of right and wrong cases with the method of varying the stimulus. This method consists in determining the intensity of the stimulus at which the subject will give a correct answer in eight out of ten judgments. The detailed procedure with the watch test, the whisper test, and the audiometer is as follows: —

Directions

a. Watch test. Blindfold the subject, close one ear with the finger or a plug. Hold the watch opposite the open ear well within hearing distance and slowly move it away, requiring the subject to say at intervals whether or not he hears it. When the point has been reached at which the subject reports that he no longer hears the watch, mark the spot on the floor with chalk. Begin beyond the point at which the watch can be heard and move it slowly toward the subject until he clearly hears it and mark as before. Then tell the subject that when the watch is presented it will always be at the same place but that, in approximately half the cases in which he is asked to judge, there will be no stimulus whatever. Then hold the watch midway between the two marks and proceed by distributing the cases in which the watch is and is not presented irregularly, but in about equal number. If the answers are correct in eight out of ten cases, measure the distance of the place of stimulation from the ear and record it as the threshold. If the answers are correct in smaller ratio than eight to ten, move the watch nearer and elicit another set of judgments, and so on until a place is found where the ratio is as required. Proceed in the same way to test the other ear.

b. Whisper test. The disadvantage of the watch test (besides variation in the loudness of tick of different watches, and the consequent absence of an abso-

lute standard) is that the sound is not one which one is accustomed to listen for, and is one which it is very easy to imagine one hears when one does not. Furthermore, there is no means of knowing certainly whether the subject actually does hear the sound; and finally, the ability to hear the tick of a watch does not always correspond entirely with the ability to hear other sounds, and is not one which is of great practical value. To meet these difficulties the whisper test has been devised.

The procedure is similar in principle to that used in the watch test, the difference being that the criterion as to whether the subject has heard is in this case the ability to repeat or write numbers which are spoken to him in a whisper. The subject is placed with one ear toward the experimenter, the other ear being plugged, and a position is found as before at which the subject can correctly reproduce numbers which are whispered to him, in eight out of ten cases. In order to insure that the numbers be pronounced with equal loudness each time, the breath should be expelled as fully as occurs in a natural expiration, and not more than eight syllables should be pronounced at one time. With these precautions, the whisper test may be made with a fair degree of accuracy, and it may be conveniently used in the schoolroom.

c. Acoumeter test. The disadvantage of both the watch and the whisper tests is that they are subject to disturbance by other sounds. Hence, a comparison

between the results with different persons is rendered somewhat uncertain and difficult. These difficulties are overcome by forms of audiometer which produce sounds of regularly varying loudness close to the ear. The instrument which is chosen for this test is the Lehmann acoumeter. This instrument consists essentially of a pair of forceps, the height of which can be varied by small and measurable amounts, so as to enable a metal ball to be dropped upon a surface of glass or cardboard from various heights.

Directions. Vary the height of the forceps in the acoumeter and determine the threshold in the same manner as in the watch test. Record this as the measure of auditory acuity. Test similarly the other ear.

Results of the experiment. The detailed results of the three auditory tests are shown in numerical form in Table XVIII, and in graphic form in Chart VI. The experience of previous classes indicates that when this experiment is made in the usual fashion, that is, when the tests are all made by different individuals, the results are so varied that little or no reliance can be placed on them. This was shown by the unsatisfactoriness of the checks which are mentioned below. It is evident from this experience that this test, while apparently a simple one to make, is one of the most difficult to give accurately. In order to insure greater uniformity in the results all the subjects were tested by the watch and the whisper method by one person, and the

TABLE XVIII. SCORES MADE BY A GROUP OF TWENTY IN THE AUDITORY TEST

Individual	*Acoumeter test*		*Watch test*		*Whisper test*	
	R. ear (millimeters)	*L. ear (millimeters)*	*R. ear (meters)*	*L. ear (meters)*	*R. ear (meters)*	*L. ear (meters)*
A.....	5.	5.	0.	0.	.42	.88
B.....	5.	4.	3.24	1.42	14.42	14.42
C.....	5.	3.	.90	.70	4.	3.6
D.....	3.5	3.5	1.03	1.14	12.6	8.
E.....	3.5	2.5	0.27	.80	20.22	20.22
F.....	3.	3.	9.30	10.90	12.90	14.41
G.....	3.	3.	10.42	10.42	14.42	14.41
H.....	2.5	2.5	3.	4.	9.	10.
I.....	2.5	2.5	1.95	1.72	9.23	9.23
J.....	2.5	2.25	4.30	3.46	11.91	11.91
K.....	2.	2.75	3.18	3.	4.26	3.80
L.....	2.	2.5	4.23	4.23	9.23	9.23
M.....	2.	2.	5.	4.22	14.12	14.12
N.....	2.	1.5	.93	1.33	9.23	10.73
O.....	1.75	2.5	1.28	.93	11.5	8.81
P.....	1.75	2.	4.	2.	7.21	4.9
Q.....	1.75	1.75	4.	4.22	14.42	14.42
R.....	1.5	3.5	3.11	.66	2.22	3.6
S.....	1.5	2.	.68	.5	11.37	.68
T.....	1.5	1.75	2.79	3.8	15.	14.42

acoumeter test was given to all by another experimenter. Even with this precaution the results from five of the subjects, B, E, F, G, and R, were unreliable on account of some limitation or defect in the procedure. The data from Subject S are not to be used in judging the reliability of the results because of the loss of one ear-drum.

The greatest difficulty encountered in giving this

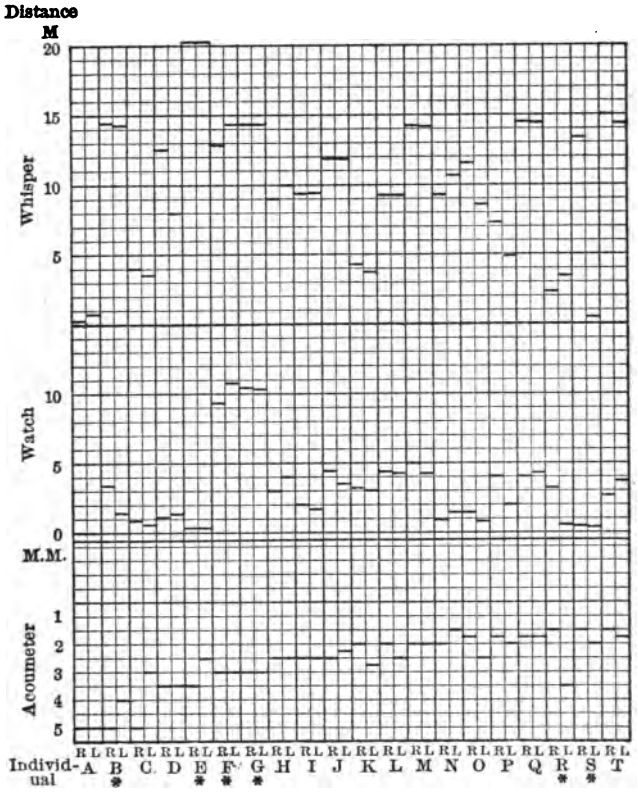

CHART VI. GRAPHIC REPRESENTATION OF THE DATA IN TABLE XVIII

R = right ear L = left ear * indicates unreliable cases

test is the interference of extraneous noises. This is true even in a relatively quiet building. In a building near which there are many street noises the difficulty would be greatly increased. Where the conditions are

unfavorable for this reason one must do his best to call for judgments at moments that are relatively quiet. Another difficulty is the inability of the unpracticed subject to pay strict attention, and to give a faithful account of what he hears. This must be overcome by taking sufficient time for the test, and by introducing a considerable number of negative cases by calling for judgments when no stimulus was given. If the subject does not pretty regularly report that he hears nothing when no stimulus is given he must be trained until he can.

It is true that none of the persons tested in this group, with but one or two possible exceptions, are very hard of hearing, and therefore there may not be any of them who need to be discovered by an auditory test. And yet if we relied on a single test there would be at least seven or eight who might be rated defective by one test or another. It appears then that much care is required at least to avoid rating persons defective who are not, and possibly also to avoid missing some who are defective.

The reliability of the results may be checked in two ways. In the first place we may compare the relative rating given to the two ears of the same person in the different tests. If one ear is rated poorer than the other in one test it should also be rated as poor by the other tests. The chart makes it easy to apply this check. Disregarding the unreliable cases, which are starred, we may examine the others to determine whether the

results from the two ears give them the same relative rating in the three tests or not. There are ten cases (A, G, H, I, J, K, L, M, Q, T) in which the rating of the two ears is not markedly different, and in which the three tests agree in giving them about the same rating. There are three cases in which one ear is given a better rating than the other in all three tests (N, O, P). There are then thirteen cases in which there is substantial agreement. On the other hand, there are two cases (C and D), in which one ear is given a widely different rating than the other in one test but not in the others. On the whole, this check is favorable to the tests.

The other check does not give quite so favorable results. We may compare the relative standing of the different persons in the three tests. Again disregarding the admittedly unreliable cases, we may examine each case to see whether there is any considerable discrepancy in the first rating. In the case of Subjects A, H, I, M, Q, and T, there is reasonably close correspondence in the three tests. C and D may be added to this list, if we take the average of the rating of the two ears in the cases in which they are not alike. In the case of L the whisper test is rather low, but not extremely so. In the case of four subjects (K, N, O, and P) there is serious discrepancy in one test — in the case of K and P in the whisper test, and in the case of N and O in the watch test. There are thus eight cases of fair agreement, and four cases of bad disagreement in respect to one test.

The tests, while not highly reliable therefore, give results which, taken singly, are of some value. To get results of greater reliability it is necessary to refine the technique far beyond that which an untrained teacher is likely to attain in giving the tests to children, or to combine the results from two or three tests.

Extension of the experiment. The types of extension of Tests 13 and 14 that would be the most useful concern the technique, or the effect of sensory defects upon the child's work in the school. The technique may be further investigated by having the same test given to the same group of persons by two or more experimenters. Cases of disagreement might then be further investigated until they were explained or the different testers came to an agreement. The effect of sensory defects on school work could be studied by testing a group of school children for sight and hearing, noting whether there were any bad uncorrected cases, and if any were discovered investigating their work to see whether the effects of the defect could be traced. If the defects could be corrected and the results noted, so much the better.

QUESTIONS ON EXPERIMENTS NOS. 13 AND 14

1. Is the dependence of intelligence upon sensory normality necessary or adventitious? Support your answer. Does sensory defect have the same effect on intelligence as defect of brain structure?
2. Trace the possible injurious physiological effects of sensory defect.
3. Show in some detail the effects of sensory defect upon the child's acquirement of experience.
4. Describe the measures which may be taken to correct or ameliorate sensory defects or to avoid some of their bad consequences.
5. Is there any reason to think that especial care is required to detect sensory defect?
6. Does the importance of sensory defect argue for the value of sense training?
7. Name other sensory defects of some consequence besides those tested in these experiments.
8. Compare sensory defects with defects in any of the perceptual processes investigated in this course.

REFERENCES

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Eulenberg, H., *and* Bach, T. *Schulgesundheitslehre* (1900), vol. 1, pp. 748 *ff.*

Experiment No. 15

TESTS OF MATURITY OF A MENTAL FUNCTION

a. Immediate memory for numbers

Problem. The second type of test with which we shall deal aims to determine the position which an individual occupies upon a scale of development. The assumption underlying such a test is that there are characteristic stages of development through which the child passes until he reaches maturity, and that tests may be devised which correspond in difficulty or in kind to the ability or the type of mental life of the child at these various stages.

The two tests which are used in this experiment will serve as examples of tests of progressive difficulty which may be used to measure the degree of mental maturity of an individual. The next step in the development of maturity tests on a systematic basis is to devise and apply many such single tests to children, in order that norms may be established. By this means a group of standardized tests may be placed at the service of the teacher or custodian of children, by which he may analyze the child's mental development qualitatively and quantitatively.

The first test deals with the relatively simple mental process of immediate rote memory, or memory span. Immediate memory develops rapidly with increasing age up to about fifteen years of age, and may be devel-

oped further by practice. This, then, is a suitable subject of a maturity test.

Material and method. Various kinds of subject-matter have been used in tests of immediate memory. The most convenient material in a number of ways consists of one-place numbers, and they have accordingly been chosen. Numbers have the advantages of being familiar, and at the same time of being relatively free from associations. This insures the use of rote instead of logical memory.

Two series of numbers are given below, so that each subject may be given a list with which he is unfamiliar. In making up the lists, any sequence which would be likely to aid the memory of the subject should be avoided. Such would be, for example, regularly ascending or descending sequences, the immediate repetition of the same number, the repetition of the same sequences in successive lists, etc.

List a:	(2) 3, 8	(6) 4, 2, 7, 5, 1, 8
	(3) 9, 4, 7	(7) 3, 9, 2, 6, 7, 5, 8
	(4) 2, 5, 1, 9	(8) 9, 5, 4, 8, 1, 7, 3, 6
	(5) 6, 8, 3, 5, 7	(9) 2, 7, 1, 6, 9, 4, 3, 8, 5
List b:	(2) 6, 1	(6) 7, 3, 6, 8, 4, 9
	(3) 4, 7, 2	(7) 2, 5, 4, 3, 8, 1, 7
	(4) 3, 8, 5, 7	(8) 5, 1, 7, 3, 4, 6, 2, 9
	(5) 4, 2, 9, 1, 5	(9) 7, 1, 3, 6, 2, 9, 8, 5, 4

The series are to be read aloud by the experimenter in order, giving the subject opportunity to reproduce each series orally. The numbers should be read in an even voice, without rhythmic grouping at about one second intervals.

b. Reconstruction of sentences

Problem. A second test of the same general nature as the preceding, but which involves a more complex sort of mental process, is the subject of this experiment. This test consists in rearranging the words of sentences which have been put into chance order. Variation in difficulty has been secured by choosing sentences of the same general character, but of increasing length. The sentences used in this experiment have been roughly standardized in difficulty by being given to a class of adults.

Material and method. The subject should not try to reconstruct the sentences until the experiment is undertaken. The measure of efficiency is the time required to reconstruct the sentences. Let the experimenter, with stop-watch in hand, present one sentence at a time to the subject visually, beginning with the shortest and advancing each time to the next longer. The time to be measured is from the presentation of the sentence until it has been correctly written. The answer is to be graded as correct if all the words are included in a grammatical and logical sentence. Minor variations from the key are to be allowed. Two series of sentences are furnished, so that each subject may have a different one. The two series are approximately equal in difficulty. They are printed in the Appendix, which see.

Treatment of results. The individual reports should

contain tables showing the series of numbers correctly reproduced and the time required to rearrange each sentence. Any variations from a correspondence between the relative length of a sentence and the time required to construct it should be explained on the basis of introspection.

The general report should generalize the data from the individual subjects, and discuss individual differences.

Results of the experiment. These tests when given to adults are, of course, not tests of maturity. The purpose of including them in a course of this sort, besides familiarizing the student with certain typical tests and methods, is to indicate some of the facts which have to be considered in interpreting the results of such tests. The two factors which are to be studied in the results to be presented are individual difference, and the chance misadaptation or favorable adaptation of a subject to an individual test.

The immediate memory span for numbers in a group of fifteen individuals varied from 6 to 9. The scores were distributed as follows: —

Frequency	*Number*
2	6
3	7
7	8
3	9

The mode of this group is 8. Because of the variation which is here evident among mature individuals,

it is manifestly a mistake to lay great stress upon the differences of one or two from a norm in a single test such as this. The combined result of a group of tests is of more significance than a single test.

Individual differences are also illustrated in the results of the tests in the reconstruction of sentences. These results also show that in this test the time required to reconstruct the sentences depends a good deal on the chance that one begins with the right or the wrong words, or starts the construction of the sentence in one way or another. Table XIX shows the scores of two groups, in Series I and II respectively.

It will be seen upon inspection of the table that there is fairly regular increase in the time required to reconstruct the sentences as they grow progressively longer, but that there are in most cases exceptions to this rule of regular increase, and in some cases the exception is notable. An illustration of a notable exception is to be found in the score of Subject F. Such cases as this show that it would be erroneous to assume — in adults at least — that a sudden and large increase in the time required indicates a limit of ability, or the demarcation between two stages or methods of procedure, for in the last two sentences this subject's score drops considerably below the average. It may be that in the case of children or of adults, with still longer and more complex sentences, a fairly definite point would be reached which would mark the limit of ability to reconstruct without the expenditure of largely increased time; but,

TABLE XIX. SCORES OF FIFTEEN INDIVIDUALS IN THE RECONSTRUCTION OF SENTENCES

Series I

Sentence No. / *Number of words*	*1* / *6*	*2* / *7*	*3* / *8*	*4* / *9*	*5* / *10*	*6* / *12*	*7* / *13*	*8* / *16*
Subject —								
A	7	10	15	17	21	28	32	36
B	20	32	19	57	32	56	75	68
C	30	32	40	32	75	60	40	50
D	9	14	17	27	19	68	47	52
E	11	18	23	34	45	117	194	150
F	13	20	30	27	160	235	47	77
G	16	25	23	45	51	79	90	225
H	20	25	22	50	38	41	73	74
Average of middle two individuals	14.5	22.5	22.5	33	41.5	64	60	72.5
Tentative standard	14	22	29	33		47	56	66

Series II

Sentence No. / *Number of words*	*1* / *6*	*2* / *7*	*3* / *8*	*4* / *9*	*5* / *10*	*6* / *12*	*7* / *14*	*8* / *16*
Subject —								
I	16	17	30	35	25	40	70	60
J	12	12	12	16	22	31	25	49
K	20	17	20	35	24	43	60	45
L	15	14	17	32	30	35	35	44
M	14	15	16	27	32	37	38	58
N	10	11	13	16	16	24	181	36
O	21	19	36	41	43	92	130	67
Score of middle individual	15	15	17	32	35	37	60	49
Tentative standard	16	15	20	30	38.5	51.2	54.25	64.8

with the possible exception of Subject E, no such point was reached in this group, and the probability is against such an interpretation of E's scores.

Extension of the experiment. There are several obvious modes of extending this experiment. By further experiments with adults the standardization of these sentences can be perfected. This might involve modifying some of the sentences, or substituting others for them. Still longer and more complex sentences could be used with adults in the attempt to reach a breaking point. Finally, as in other tests, there is wide opportunity of the standardization of this test with children.

QUESTIONS AND TOPICS FOR DISCUSSION

1. Are any devices used to keep the series of numbers in mind?
2. Discuss the suitability of this method as a test of mental maturity. What function is involved?
3. What methods are used to solve the problem of reconstructing the sentences? Are different methods used? Are different methods used with sentences of different length or degree of difficulty?
4. Does your knowledge of child psychology lead you to think that children of different ages might use different methods?
5. What type of mental activity is tested in this experiment?
6. Is the effect of increasing mental maturity to introduce different mental processes into the performance of such tasks as these? If not what change does take place?
7. Examine the reports of tests to discover in what kinds of mental process the greatest change with mental maturity appears.
8. Which kind of test, one which shows large, or one which shows small, progress with age, is better suited to the mental examination of children?

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Experiment No. 16

CORRELATION BETWEEN TESTS

Problem. The measurement of correlation is important in the study of a variety of problems. In educational psychology correlation refers to the extent to which the presence of a certain degree of one mental trait implies the presence of a second trait in a corresponding degree. Put in another way, the degree of correlation between two traits may be measured by the degree of correspondence between the two series or orders when the individuals of a group are ranked according to their efficiency in each of the two processes.

Some of the various methods of calculating degrees of correlation are therefore based upon the arrangement of a group of individuals in ranks. For example, suppose we wish to determine the correlation between height and weight in a group of persons. After each individual has been weighed and measured the individuals are given a ranking according to each of the two characteristics separately. If the same person stands at the head of the two lists, — that is, if the tallest person is also the heaviest, — and if each person occupies the same position in the two rankings all the way down, there is complete positive correlation. On the other hand, if the individual who is at the top of one ranking is at the bottom of the second, and if this relation is

maintained throughout, there is complete negative correlation. If such a relation obtains between the two rankings as would be ascribed only to the operation of chance, there is no correlation. More exact methods take account not simply of the *rank* or *position* of an individual, but also of the *amount* of his deviation from a central tendency.

For the study of the correlation between mental traits various methods have been used. A brief account of the more important methods is given in the discussion of the results of this experiment. For fuller discussion the reader is referred to the convenient account which is given by Whipple in his *Manual of Mental and Physical Tests*. Whipple appends a bibliography which may be used as a guide to further study. Examples of the extensive use of the correlation method in psychology are to be found in the investigations of Burt and Simpson.

These and other investigations have made it clear that there is a high degree of correlation between some mental traits, and a low degree between others. The purpose of this experiment is to measure the correlation between mental traits which are representative of various groups of mental abilities. Three traits or forms of ability will be measured, one of them being tested twice, and the four correlations between the various pairs will be found.

Material and method. The abilities which are to be measured are (1) rate of tapping, as an illustration of

motor ability; (2) pitch discrimination, as an illustration of sensory discrimination; and (3) the opposites test, as an illustration of the more complex mental processes.

(1) The tapping test is a simple one to perform. By means of a stop-watch and an apparatus for recording the number of taps the rapidity of tapping with the hand is measured. (See Figure 7.) The number of taps

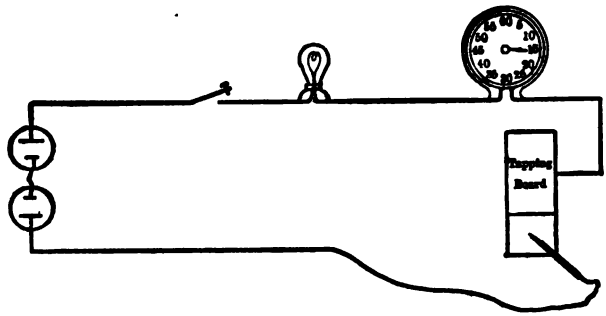

FIG. 7. DIAGRAM OF THE CONNECTIONS FOR THE TAPPING APPARATUS

is recorded by an electric counting device. A stylus and brass plate are in circuit with an electric battery or other circuit and with an electric clock. Each time the circuit is closed by bringing the stylus in contact with the brass plate, the hand of the clock moves forward one point. The procedure then is to tap continuously for five seconds, as rapidly as possible, and then read off the record on the clock. The clock should be set at zero before each trial by turning the hand forward. In tapping, the forearm should be allowed to

rest on the table, and the movement should be made with the wrist. Three trials of five seconds duration each should be made, and the average of the three taken.

(2) The test in pitch discrimination consists in the determination of the amount of difference between two tones which must exist in order that one may be distinguished as higher than the other. A convenient and accurate form of apparatus to use in measuring pitch discrimination is the tuning fork. In the present experiment a standard tuning fork of 435 vibrations is used, and a number of other forks differing from it by varying numbers of vibrations for making the comparisons.

The same general method of procedure is to be used as in the test of auditory acuity: that is, the comparison should begin with tones which can be easily distinguished and proceed gradually to the smaller intervals, until a point is reached at which eight out of ten judgments are correct. The interval between the two tones as found thus may be recorded as the descending threshold. This threshold is sufficiently reliable.

Several features of procedure should be mentioned. The fork which is to be compared with the standard should first be put in position with the standard fork on the sounding box. Then, after a " ready " signal, one of the forks should be struck, then damped, and then the second struck and damped. While one fork is sounding the other one should be damped to pre-

vent sympathetic vibration. The duration of each tone and of the interval between them should be uniformly about two seconds. Care should be taken to avoid any regularity in striking either the standard or the comparison tone first. Occasionally the same tone should be struck twice in succession as a check.

(3) The procedure in the opposites test is simple. A list of words is furnished and the problem is to supply for each one a word which has the opposite meaning. The task is to supply the opposite word within a time limit of ten seconds for each word. The response words should be written, and the time may be extended until the writing of a word is completed if it has been begun within the ten seconds. In order that the same test may be used by subject and experimenter, the subject should take the printed list of words and cover it with a sheet of paper. Each word may be uncovered by sliding a card so that the opening comes over it at a signal given by the experimenter at the interval mentioned. The subject should study the word until the next signal is given or until the opposite is found. The score consists in the total number of opposites correctly given. The response, to be correct, need not be the exact word given in the response list, but should be a synonym of it. The lists of stimulus words and specimen opposites are given in the Appendix, which see.

Treatment of results. Since the chief results in this experiment appear from a comparison of the results

from the various individuals of the group, each member of the class should calculate one correlation coefficient. The members of the class may be numbered. Number 1 should calculate the first correlation mentioned below, number 2 the second, and so on. Number 5 should begin at the first, and so on. The correlations to be calculated are as follows: —

1. Between rate of tapping and pitch discrimination.
2. Between rate of tapping and first opposites test.
3. Between pitch discrimination and first opposites test.
4. Between first and second opposites tests.

For convenience in arranging the list of subjects, in order to calculate the correlations, they should be designated by their number. Each person should therefore indicate his number on his report.

Each individual report should include, beside the usual preliminary statement of the problem and method, the full account of the results of each test, including introspections and description of the difficulties which were encountered. The individual report should also include the full calculation of the correlation coefficient, and not merely the coefficient itself.

The general report should compare the degrees of correlation among the results of the various tests, and should enter upon a discussion of the significance of the differences found. Reference should be made to attempted explanations of correlation and differences in correlation among mental processes, such as Krueger

and Spearman's theory of a central intelligence or of a hierarchy of intelligences.

Results of the experiment. The scores in the three tests used in this experiment are given in Table XX,

TABLE XX. SCORES OF NINETEEN INDIVIDUALS IN THE TESTS

Individual	*Rate of tapping*	*Pitch discrimination*	*Opposites test I*	*Opposites test II*
1	36	8	17½	10
2	38	½	20½	20
3	38½	1	20½	13
4	40	17	26	..
5	40½	2	27½	..
6	41½	2	17½	11
7	41½	8	16	6
8	42	3	15½	10
9	43	17	22	17½
10	43½	½	20½	10
11	45	½	18½	11
12	46	1	15	10
13	46	½	23½	16
14	47	2	17½	18½
15	47½	½	24	18
16	47½	½	24	..
17	49½	½	26	..
18	53	2	19½	13
19	..	8	26	..

with the subjects arranged in their order in the tapping test. Charts VII and VIII and Table XXI illustrate methods of displaying and calculating the correlation between the first and second opposites tests. These results are presented more for the purpose of illustrating some of the methods of examining correlation and

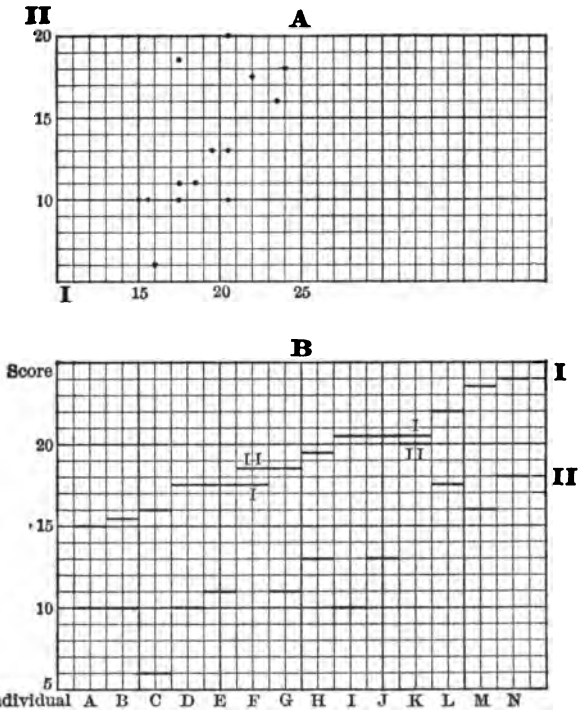

CHART VII. GRAPHIC REPRESENTATION OF THE CORRELATION BETWEEN THE FIRST AND SECOND OPPOSITES TESTS

some of the requirements of valid procedure than as a basis for much discussion of the facts of correlation themselves.

Table XXI illustrates a form of procedure which is necessary, in many cases, to obtain a reliable calculation of correlation, that is, the determination first of the reliability of the measures secured in each test by

itself. This is secured by finding the correlation between two performances in the same test, using, where the nature of the test demands it, different subject-

TABLE XXI. CORRELATION BETWEEN FIRST AND SECOND OPPOSITES TESTS

Individual	*Score in I*	*Score in II*	*x diff. of scores in I from average*	*y diff. of scores in II from average*	x^2	y^2	xy
1.....	15	10	−4	−3	16	9	+12
2.....	15.5	10	−3.5	−3	12.25	9	+10.5
3.....	16	6	−3	−7	9	49	+21
4.....	17.5	10	−1.5	−3	2.25	9	+ 4.5
5.....	17.5	11	−1.5	−2	2.25	4	+ 3.0
6.....	17.5	18.5	−1.5	+5.5	2.25	30.25	− 8.25
7.....	18.5	11	− .5	−2	.25	4	+ 1
8.....	19.5	13	+ .5	0	.25	0	0
9.....	20.5	10	+1.5	−3	2.25	9	− 4.5
10.....	20.5	13	+1.5	0	2.25	0	0
11.....	20.5	20	+1.5	+7	2.25	49	+10.5
12.....	22	17.5	+3	+4.5	9	20.25	+13.5
13.....	23.5	16	+4.5	+3	20.25	9	+13.5
14.....	24	18	+5	+5	25	25	+25
Average.	19	13			105.5	226.5	101.75

$$r = \frac{\Sigma x \cdot y}{\sqrt{\Sigma x^2 \cdot \Sigma y^2}} = \frac{101.75}{\sqrt{105.5 \times 226.5}} = \frac{101.75}{154.6} = .65.8$$

$$\left(\text{or } \frac{\text{sum of the products of } x \text{ and } y}{\text{square root of (the sum of } x^2 \times \text{the sum of } y^2)}\right)$$

matter in the two performances. If this correlation is not fairly high — above .60 — the degree of correlation between this test and others is of little significance, since the scores are not accurate measures of the ability

in question. A formula has been developed by Spearman to correct a coefficient of correlation when it is

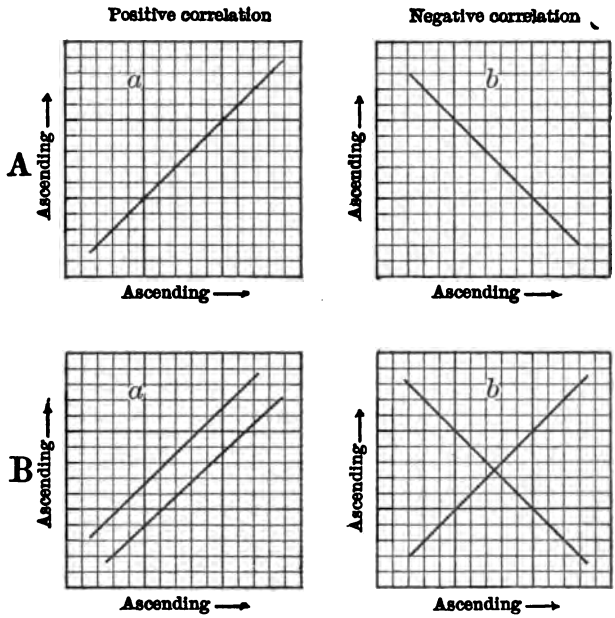

CHART VIII. DIAGRAM ILLUSTRATING THE INTERPRETATION OF THE TWO GRAPHIC METHODS OF DISPLAYING CORRELATION USED IN CHART VII

(A) illustrates the method of plotting the position of each individual with reference to the two tests by designating his position with reference to both coördinates, one of which represents the scale of scores in one test and the other the scale in the second test. (B) illustrates the method in which the positions in the two tests are plotted separately with reference to the same coördinate.

reduced by lack of precision in the results in the individual tests, but the reliability of this formula is doubtful, and it is far better to perfect the methods of

giving the tests until their results are consistent. In the case before us two series of opposites were used with the same persons. The correlation between them appears from the table to be satisfactory ($r = 65.8$), though it might well be higher.

This table illustrates the most precise method of calculating correlation, namely, by the Pearson products-moment method. This and the two methods which Spearman has derived, the rank method and the foot-rule method, are described in Whipple and critically discussed in Brown.

The products-moment method may be compared with two graphic methods by reference to Chart VII. In the first graphic method, designated A, the two scores of each individual are represented by a single position. This position is determined by reference to two coördinates, one of which provides the scale of performance in one of the tests, and the other the scale of performance in the other test.

If the dots which indicate these positions group themselves along a line which divides the angles formed by the two coördinates, such as the line in figure A*a*, Chart VIII, there is evidence of correlation, since each individual occupies about the same position in the two tests. If high standing in one test is regularly accompanied by low standing in the other, so that the correlation is negative, the dots will be grouped about a line having somewhat the general position of that in A*b*, Chart VIII. In the case before us the grouping indi-

cates a fairly high degree of correlation, as does the correlation coefficient.

In Chart VII, B, another graphic method is illustrated. In this case the scores of each test are plotted separately, and are represented by a scale or scales along a single coördinate. The positions in the other direction are arbitrarily arranged along the other coördinate. Thus the scores in each test are represented by a series of dots or lines, and the relation of the two series represents the degree of correlation present. Chart VIII, B, *a* and *b*, represent regular and extreme positive and negative correlation, respectively, when one of the series is arranged in regular ascending or descending order.

Chart VII, B, indicates an approach to a parallelism of the two lines, indicating considerable positive correlation. The ready comparison is made possible, as already suggested, by arranging one of the series in ascending or descending order. In this case the scores of Test I were arranged in ascending order.

Contrasted with the considerable positive correlation shown in Chart VII, Chart IX, which represents the scores of the tapping and pitch discrimination tests, exhibits certainly no positive correlation, and no large amount of correlation of any sort.

Likewise the products-moment method gives no correlation between the scores in the rate of tapping and the first opposites tests ($r = .07$).

There are also other frequently used methods of

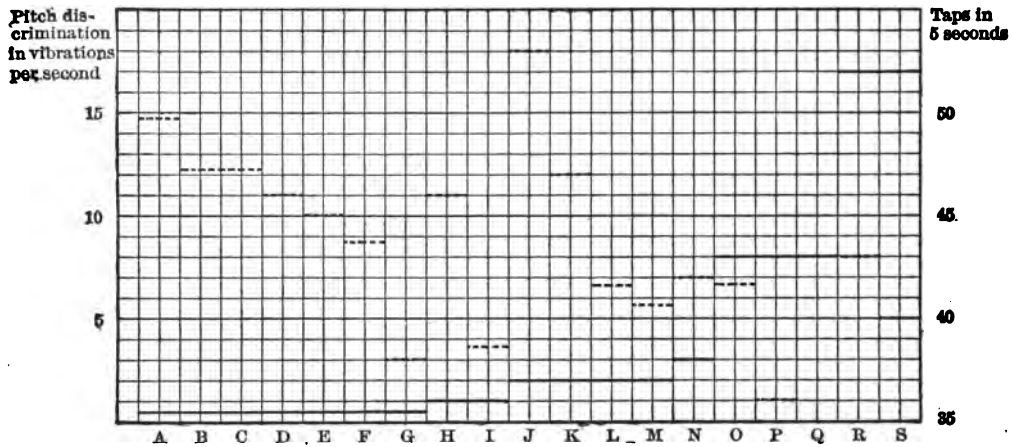

CHART IX. GRAPHIC REPRESENTATION OF THE CORRELATION BETWEEN RATE OF TAPPING AND PITCH DISCRIMINATION

showing correlation. One rough method was illustrated in formulating the results of Experiment No. 11. Another method of somewhat similar nature was used by W. F. Dearborn and others in studying school grades. This method consists in arranging the two sets of measures in two distributions, dividing the measures in each distribution into three or more equal groups according to their rank, and finding the percentage of cases which fall into the corresponding groups in the two arrays. This percentage has been termed the percentage of retention. The significance of the percentage of retention is not altogether clear. It certainly varies according to the number of groups used, since this affects the percentage which represents the lack of any positive correlation. Further, where three groups are used, at least, a purely chance relationship and complete negative correlation might be represented by the same percentage, 33⅓.

In general it may be laid down as a principle that whenever possible it is better to use complete frequency tables on the same principle as Chart VII, A, or arranged as in Experiment No. 11, or some graphic method that displays all the facts. These facts should be analyzed and the various types of cases classified. Where it is highly desirable to get an expression of the general degree of correlation, one of the crude methods may be used where only very rough results are desired. When more precise results are desirable the Pearson method is to be recommended, but it must

be remembered that the same single coefficient may represent many different sorts of relationship.

With reference to the facts of correlation brought out in this experiment, it appears that, so far as our results go, motor dexterity is not correlated positively with sensory discrimination, or sensory discrimination with the recognition of the relationship of opposites. This result is fairly typical. It was planned to include another function comparable in the kind of mental performance required with the opposites test, named the Ries test, referred to in the list of references. But the two examples of the Ries test which were used did not give correlated results, and it was not included.

Extension of the experiment. This experiment may be extended by attempting to work out satisfactory forms of the Ries test, and also by including other tests. See Burt and B. R. Simpson.

QUESTIONS AND TOPICS FOR DISCUSSION

1. Suggest some of the practical bearings of the facts regarding correlation.
2. What is the relation between correlation of mental traits and formal discipline?
3. What bearing does the presence or absence of correlation have upon the view of the mind as made up of relatively isolated traits or of closely related ones?
4. Compare the concepts of correlation and of specialization in their bearing on vocational guidance.
5. How may correlation be used in selecting a test for mental maturity or for intelligence?
6. Illustrate concretely the fact that the same correlation coefficient may indicate any one of several kinds of relationship. What is the practical application of this fact?
7. Indicate roughly how much reliance can be placed on the result of the application of a single test to an individual to measure the presence of some trait, when the correlation (r) between the scores in the test and the trait is .70.
8. Indicate how irrelevant factors, as age or practice, may falsify a correlation coefficient if they are not taken account of.
9. What is the effect of chance errors? How are they to be treated?

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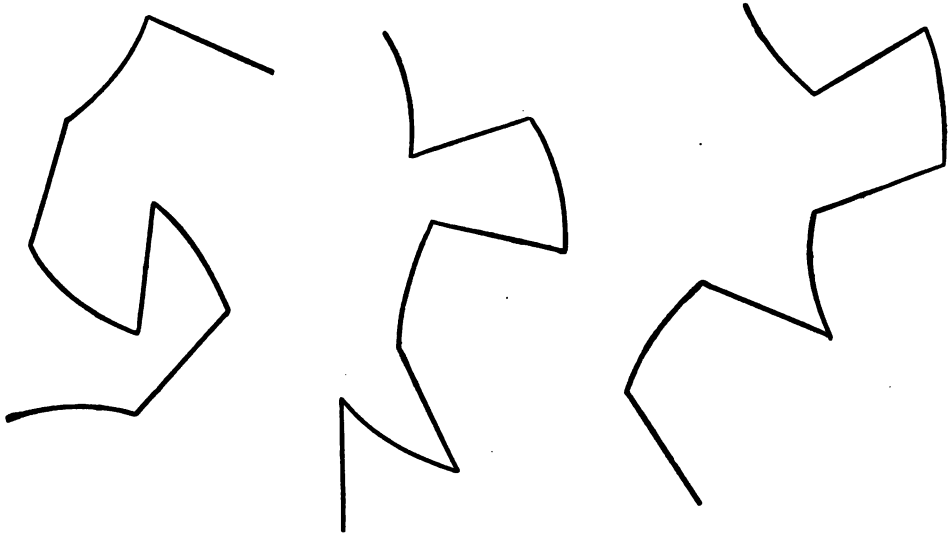
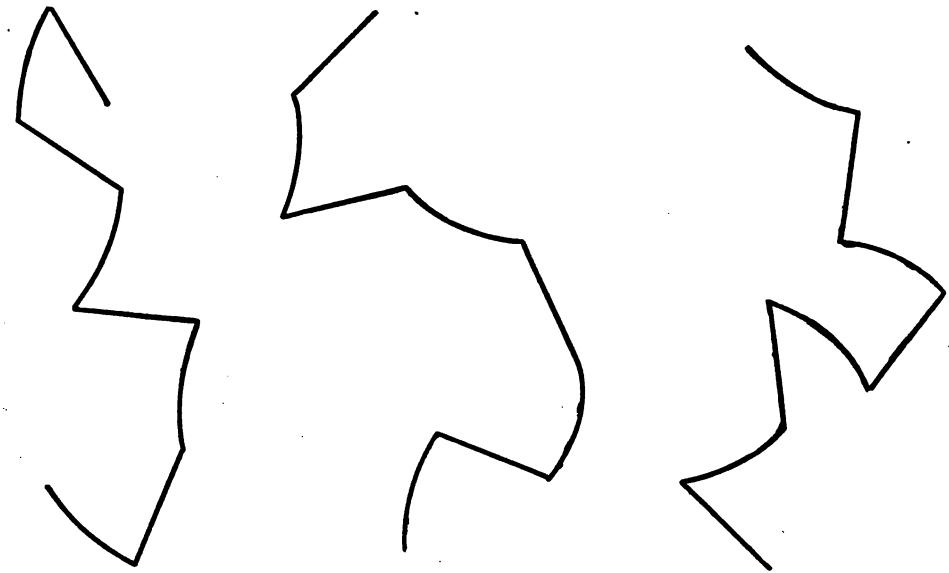
APPENDIX

FIGURES AND TESTS FOR USE WITH THE EXPERIMENTS



FIGURES FOR EXPERIMENT 2 — PERCEPTUAL LEARNING



FIGURES FOR EXPERIMENT 2—PERCEPTUAL LEARNING

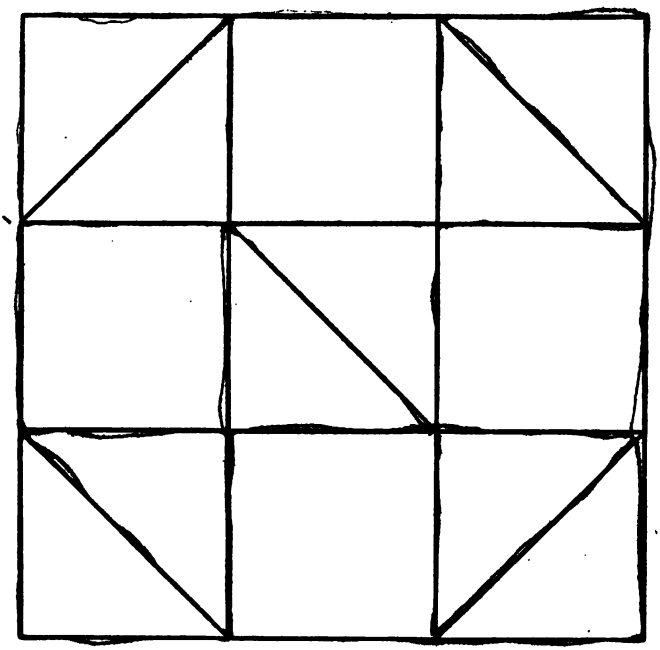


FIGURE FOR EXPERIMENT 3—TAIT UNICURSAL LABYRINTH

SERIES OF SYLLABLES FOR EXPERIMENT 5

Series I	*Series Ia*	*Series II*
geb	pos	wix
wap	gaj	pif
ker	yed	zin
sub	bik	faq
ren	nal	pex
yat	wur	zan
ref	juv	fos
biv	mip	nel
lin	buv	ber
taz	yot	rul
fud	dik	kif
zib	caz	lod
mep	mub	kir
dos	gom	ral
rel	cug	fup

Series III	*Series IV*	*Series V*
zed	paf	pom
vof	kuj	loy
lud	dal	feg
fip	ros	hol
mol	tiv	cag
lat	kay	kas
ced	tud	lim
maf	soz	rin
sug	mez	nop
rol	gir	det
dut	fon	tur
taj	vid	rix
pud	sim	lez
hov	kaq	gim
vul	cer	dak

POEM TO BE USED IN EXPERIMENT 6

ENOCH ARDEN

Long lines of cliff breaking have left a chasm;
And in the chasm are foam and yellow sands;
Beyond, red roofs about a narrow wharf
In cluster; then a moulder'd church; and higher
A long street climbs to one tall-tower'd mill;
And high in heaven behind it a gray down
With Danish barrows; and a hazelwood,
By autumn nutters haunted, flourishes
Green in a cuplike hollow of the down.
Here on this beach a hundred years ago,
Three children of three houses, Annie Lee,
The prettiest little damsel in the port,
And Philip Ray, the miller's only son,
And Enoch Arden, a rough sailor's lad
Made orphan by a winter shipwreck, play'd
Among the waste and lumber of the shore,
Hard coils of cordage, swarthy fishing-nets,
Anchors of rusty fluke, and boats up-drawn;
And built their castles of dissolving sand
To watch them overflow'd, or following up
And flying the white breaker, daily left
The little footprint daily wash'd away.

A narrow cave ran in beneath the cliff;
In this the children play'd at keeping house.
Enoch was host one day, Philip the next,
While Annie still was mistress; but at times
Enoch would hold possession for a week:
"This is my house and this my little wife."
"Mine too," said Philip; "turn and turn about";
When, if they quarrell'd, Enoch stronger-made
Was master. Then would Philip, his blue eyes
All flooded with the helpless wrath of tears,

Shriek out, "I hate you, Enoch," and at this
The little wife would weep for company,
And pray them not to quarrel for her sake,
And say she would be little wife to both.

But when the dawn of rosy childhood past,
And the new warmth of life's ascending sun
Was felt by either, either first his heart
On that one girl; and Enoch spoke his love,
But Philip loved in silence; and the girl
Seem'd kinder unto Philip than to him;
But she loved Enoch, tho' she knew it not,
And would if ask'd deny it. Enoch set
A purpose evermore before his eyes,
To hoard all savings to the uttermost,
To purchase his own boat, and make a home
For Annie; and so prosper'd that at last
A luckier or a bolder fisherman,
A carefuller in peril, did not breathe
For leagues along that breaker-beaten coast
Than Enoch. Likewise had he served a year
On board a merchantman, and made himself
Full sailor; and he thrice had pluck'd a life
From the dread sweep of the down-streaming seas,
And all men look'd upon him favorably.
And ere he touch'd his one-and-twentieth May
He purchased his own boat, and made a home
For Annie, neat and nestlike, halfway up
The narrow street that clamber'd toward the mill.

Then, on a golden autumn eventide,
The younger people making holiday,
With bag and sack and basket, great and small,
Went nutting to the hazels. Philip stay'd —
His father lying sick and needing him —
An hour behind; but as he climb'd the hill,
Just where the prone edge of the wood began
To feather toward the hollow, saw the pair,
Enoch and Annie, sitting hand-in-hand,

His large gray eyes and weather-beaten face
All-kindled by a still and sacred fire,
That burn'd as on an altar. Philip look'd
And in their eyes and faces read his doom;
Then, as their faces drew together, groan'd,
And slipt aside, and like a wounded life
Crept down into the hollows of the wood;
There, while the rest were loud in merry-making,
Had his dark hour unseen, and rose and past
Bearing a lifelong hunger in his heart.

So these were wed, and merrily rang the bells,
And merrily ran the years, seven happy years,
Seven happy years of health and competence,
And mutual love and honorable toil,
With children, first a daughter. In him woke,
With his first babe's first cry, the noble wish
To save all earnings to the uttermost,
And give his child a better bringing-up
Than his had been, or hers; a wish renew'd,
When two years after came a boy to be
The rosy idol of her solitudes,
While Enoch was abroad on wrathful seas,
Or often journeying landward; for in truth
Enoch's white horse, and Enoch's ocean-spoil
In ocean-smelling osier, and his face,
Rough-redden'd with a thousand winter gales,
Not only to the market-cross were known,
But in the leafy lanes behind the down,
Far as the portal-warding lion-whelp
And peacock yew-tree of the lonely Hall,
Whose Friday fare was Enoch's ministering.

Then came a change, as all things human change.
Ten miles to northward of the narrow port
Open'd a larger haven. Thither used
Enoch at times to go by land or sea;
And once when there, and clambering on a mast
In harbor, by mischance he slipt and fell.

A limb was broken when they lifted him;
And while he lay recovering there, his wife
Bore him another son, a sickly one.
Another hand crept too across his trade
Taking her bread and theirs; and on him fell,
Altho' a grave and staid God-fearing man,
Yet lying thus inactive, doubt and gloom.
He seem'd, as in a nightmare of the night,
To see his children leading evermore
Low miserable lives of hand-to-mouth,
And her he loved a beggar. Then he pray'd,
"Save them from this, whatever comes to me."
And while he pray'd, the master of that ship
Enoch had served in, hearing his mischance,
Came, for he knew the man and valued him,
Reporting of his vessel China-bound,
And wanting yet a boatswain. Would he go?
There yet were many weeks before she sail'd,
Sail'd from this port. Would Enoch have the place?
And Enoch all at once assented to it,
Rejoicing at that answer to his prayer.

So now that shadow of mischance appear'd
No graver than as when some little cloud
Cuts off the fiery highway of the sun,
And isles a light in the offing. Yet the wife —
When he was gone — the children — what to do?
Then Enoch lay long-pondering on his plans:
To sell the boat — and yet he loved her well —
How many a rough sea had he weather'd in her!
He knew her, as a horseman knows his horse —
And yet to sell her — then with what she brought
Buy goods and stores — set Annie forth in trade
With all that seamen needed or their wives —
So might she keep the house while he was gone.
Should he not trade himself out yonder? go
This voyage more than once? yea, twice or thrice —
As oft as needed — last, returning rich,
Become the master of a larger craft,

With fuller profits lead an easier life,
Have all his pretty young ones educated,
And pass his days in peace among his own.

Thus Enoch in his heart determined all;
Then moving homeward came on Annie pale,
Nursing the sickly babe, her latest-born.
Forward she started with a happy cry,
And laid the feeble infant in his arms;
Whom Enoch took, and handled all his limbs,
Appraised his weight and fondled fatherlike,
But had no heart to break his purposes
To Annie, till the morrow, when he spoke.

Then first since Enoch's golden ring had girt
Her finger, Annie fought against his will;
Yet not with brawling opposition she,
But manifold entreaties, many a tear,
Many a sad kiss by day, by night, renew'd —
Sure that all evil would come out of it —
Besought him, supplicating, if he cared
For her or his dear children, not to go.
He not for his own self caring, but her,
Her and her children, let her plead in vain;
So grieving held his will, and bore it thro'.

For Enoch parted with his old sea-friend,
Bought Annie goods and stores, and set his hand
To fit their little streetward sitting-room
With shelf and corner for the goods and stores.
So all day long till Enoch's last at home,
Shaking their pretty cabin, hammer and axe,
Auger and saw, while Annie seem'd to hear
Her own death-scaffold raising, shrill'd and rang,
Till this was ended, and his careful hand, —
The space was narrow, — having order'd all
Almost as neat and close as Nature packs
Her blossom or her seedling, paused; and he,
Who needs would work for Annie to the last,
Ascending tired, heavily slept till morn.

TEXTS FOR USE WITH EXPERIMENT 9

Texts Nos. 1, 2, 3, and 5 are from Irving King's *Psychology of Child Development* (University of Chicago Press), by courtesy of author and publishers.

Text No. 4 is from Stevenson's *Treasure Island*, by courtesy of Charles Scribner's Sons.

No. 1 — 11-Point Type, 24 Ems Line

Hitherto we have not raised the question as to how far it is safe for us to generalize the conclusions of individual studies. Granting that they have all, as far as they go, been carefully made, we nevertheless see at once that a slight change in locality, or more especially in social status of the subjects, might modify very materially many of the details. This is illustrated most markedly in the difference in the ideals of the London board-school children and those of the children attending the better schools of the middle and upper classes. Still, even here the difference is rather in degree than in kind. It is safe to assume that every normal child has certain characteristic reactions in virtue of his being a developing organism. We have endeavored in selecting the material for this study to take that which

emphasized the broad general tendencies rather than what on its face is merely particular or at least more contingent. The further question as to how far the individual child may be expected to vary from the norms, if these could only be established, is also an interesting one. It was pointed out on an earlier page that the younger the child, the more nearly does it approach a common type. It is by all means likely that the nearer maturity the child approaches, the more we may find him varying from the supposedly common type. In fact, it becomes less and less correct to speak of types as we advance to the more mature forms. The type back of the adult can be only the vaguest and most unilluminating affair. With the child it represents a definite body of tendencies to act in certain ways that practically all children will possess. It would be difficult to chart variations from psychic norms, but curves made out for the physical side are interesting and are probably a fair index to variation in general. We adopt from Burk a curve covering 45,000 boys and 43,000 girls.

No. 2 — 11-Point Type, 12 Ems Line

No elaborate discussion or criticism of the methods by which the preceding material has been gathered can be attempted. We have gone on the assumption that the various studies have been, at least in general, reliable. The interests that have been mentioned are, most of them, well recognized by all observers of children, and, while there may be errors in observing and interpreting the facts here set forth, the general scheme as a whole seems fairly consistent when we reflect upon the great variety of sources from which the material has come. The whole subject of methodology does, however, need a thorough investigation. The object of all this class of studies should be to get accurate data as to the child's spontaneous expressions and activities, with definite record as to age, sex, and previous life-

history. Every study must be accompanied by a careful statement of the conditions under which the material is secured. The real child-psychologists are endeavoring more than ever before to devise tests that will eliminate as nearly as possible

No. 3 — 7-Point Type, 24 Ems Line

Of the methods actually used a few words may be said. Some studies can be made entirely by observation of children, as, for example, in their games, clubs, etc., and a great many lines of interest can be assumed by this method. Most investigators have, however, placed great dependence on some sort of vocal or written expression from the child. Of such expressions, two general sorts have usually been sought: *first*, those involving a certain amount of introspection on the part of the child, including his direct statements as to his desires, likes and dislikes, or even more subjective information about present mental states, motives, etc. Answers are also sought to questions that do not exactly require introspection, and yet are aimed to throw direct light on internal attitudes. *Secondly*, such expressions of the child as drawings, compositions, and the like, arranged to throw indirect light on the child's subjective attitudes and character. Manifestly the latter class of material is much more reliable if the investigator is only skilful enough to read it aright. There is, of course, always the danger of finding in such things what is really not there, or at most only slightly. The methods that rely on the direct statements of children regarding themselves are, it seems to us, of questionable value, especially if used on children before the adolescent years. It would be worth while even to test carefully their reliability for adolescents and adults. Reminiscences of interests of earlier periods, whether written by children or adults, are still more questionable for anything like accurate conclusions. With children, for example, the tendency is always in recording some childish interest, such as playing with dolls, to locate it far back in infancy, even when it has been of vital concern to them until very lately. So with adults, it is certainly unsafe to rely, except in a general way, on the accounts they give of their childish interests. Not only does the average person read much into his early life that he has really come to the realization of only in later years, but he also cannot be expected to tell with any accuracy when he had certain interests, and

when and how they culminated. Except to the trained observer, all the early life is apt to be read in terms of mature interests and attitudes. This is illustrated by the rarity of those people who can put themselves in any true sense in a child's place and appreciate his point of view. Judged by the criteria of good experiments, offered above, many of the articles quoted fall short, and yet it is worth while to bring together what they offer — to take account of stock, as it is. If it is unsatisfactory, we at least have the ground cleared for a new series of endeavors. We shall not attempt in this chapter to add anything to the already voluminous investigations of this period, but rather to get at a point of view from which the material already collected can be interpreted. This is the greatest need at present. There are many problems of adolescence, it is true, in which there should be much more research, but it seems hardly wise to heap up more material until we have taken our bearings in what we already have. It is inevitable that the hypotheses of the pioneer students of this period of development should have been somewhat superficial. In collecting a new set of facts, it is impossible to know which to select as the truly characteristic ones, and which to regard as the more superficial or as due to artificial conditions. But we have on hand now material enough regarding adolescent attitudes to look with assurance for some principles of interpretation. The period comprises the five to ten years immediately succeeding puberty.

No. 4 — 11-Point Type, 24 Ems Line, Narrative

I was drinking in his words, and smiling away, as conceited as a cock upon a wall, when, all in a breath, back went his right hand over his shoulder. Something sang like an arrow through the air: I felt a blow and then a sharp pang, and there I was pinned by the shoulder to the mast. In the horrid pain and surprise of the moment — I scarce can say it was by my own volition, and I am sure it was without a conscious aim — both my pistols went off, and both escaped out of my hands. They did not fall alone; with a choked cry, the coxswain loosed his grasp upon the shrouds, and plunged head first into the water. Owing to the cant of the vessel, the masts hung far out over the water, and from my perch on the cross-trees I had nothing below me but the surface of the bay. Hands, who was not so far up, was, in consequence, nearer to the ship, and fell between me and the bulwarks. He rose once to the surface in a lather of foam and blood, and then sank again for good. As the water settled, I could see him lying huddled together on the clean,

bright sand in the shadow of the vessel's sides. A fish or two whipped past his body. Sometimes, by the quivering of the water, he appeared to move a little, as if he were trying to rise. But he was dead enough, for all that, being both shot and drowned, and was food for fish in the very place where he had designed my slaughter. I was no sooner certain of this than I began to feel sick, faint, and terrified. The hot blood was running over my back and chest. The dirk, where it had pinned my shoulder to the mast, seemed to burn like a hot iron; yet it was not so much these real sufferings that distressed me, for these, it seemed to me, I could bear without a murmur; it was the horror I had upon my mind of falling from the cross-trees into that still green water, beside the body of the coxswain. I clung with both hands till my nails ached, and I shut my eyes as if to cover up the peril. Gradually my mind came back again, my pulses quieted down to a more natural time, and I was once more in possession of myself. It was my first thought to pluck forth the dirk; but either it stuck too hard or my nerve failed.

No. 5 — 11-Point Type, 24 Ems Line, Speed

From one point of view, every spontaneous expression of the growing child has a teleological significance; that is, its full meaning comes out only in connection with the completer development of succeeding years. For such to be the case does not, however, render less valid the activities of the child for himself. The criterion of value for the future is necessarily one for the observer, one to be applied only after the evolution has been completed, and when we can look back and interpret the incomplete in terms of the complete. It may be perfectly legitimate in philosophy to use such a standpoint, but for psychology the criterion must be in terms of present function. From this point of view we have outlined the unfolding of the child's interests and dispositions to certain sorts of action. Each period of development has its own justification, no matter what comes before or after. If a period of well co-ordinated and definitely directed modes of expression is made possible by the half instinctive and impulsive activities of earlier years,

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these earlier years were not *mere* terms of preparation. Their activities are as truly expressions of the meaning of life to the child as are the so-called fuller activities of later life to the mature individual. In the eyes of the adult the child's responses are very inadequate, but in the child's situation, with his undeveloped organism, they may be, and undoubtedly are, as complete and adequate as are the adult's. A child is not an imperfect embodiment of the powers of the adult; neither is the child's environment the differentiated one of maturity. It is because the child and his environment are separated, and because into each, in its isolation, are read the meaning that attaches to them for maturity, that the childish activities and interests come to be regarded as merely preparations or promises of future efficiency. And yet how shall we know, in studying any given point in mental development, whether the interaction of the various elements is really what it ought to be? Does this demand the bringing in of a criterion from a later period?

FIGURES AND WORDS FOR USE IN EXPERIMENT 10

PART I

A	*B*
824397	travel
652834	factor
394275	horses
314927	stolid
425768	salmon
	farmer

PART II

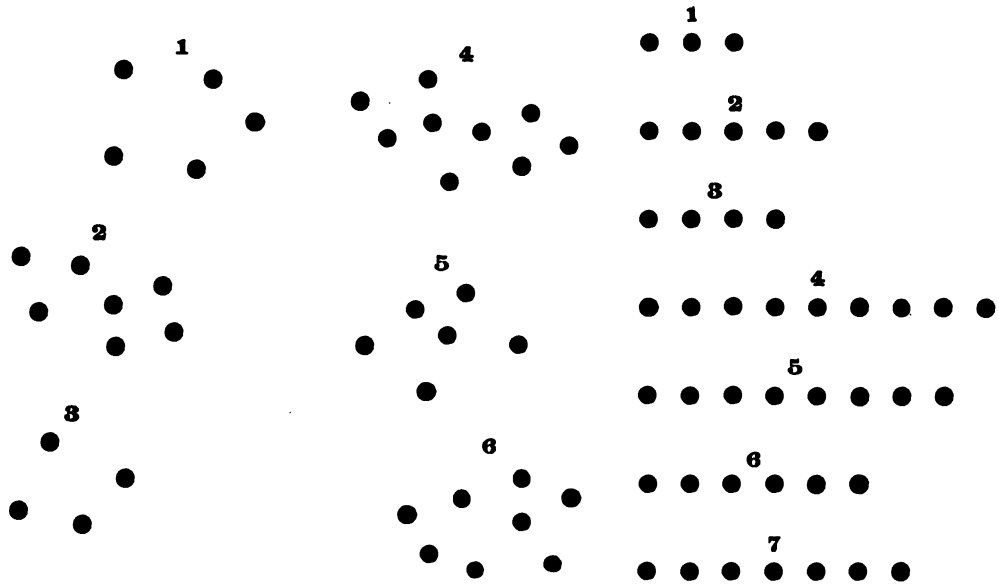
A					*B*
gup	faj	rud	fon	sil	Would you like to go?
sim	ner	zat	len	cem	There are two left.
pud	jid	soq	rux	tor	Let us take the car.
lor	min	nof	rus	reb	Why did you remain?
tof	ris	zer	div	rov	The sun has come up.
fim	tok	lox	sif	ras	Do not wait longer.

PART III

A	*B*
governmental	tachistoscopic
transcontinental	eudaemonistic

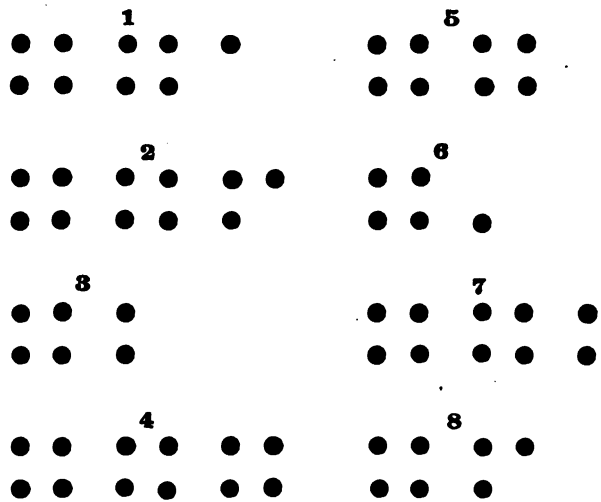
PART IV

A	*B*
education	carruage
improtant	cultiwate
measuded	argument
orthodox	trauslate
beginning	establish
delicate	stamdard



MATERIAL FOR USE WITH EXPERIMENT 12—APPREHENSION OF NUMBER EXPERIMENT

SERIES I SERIES II



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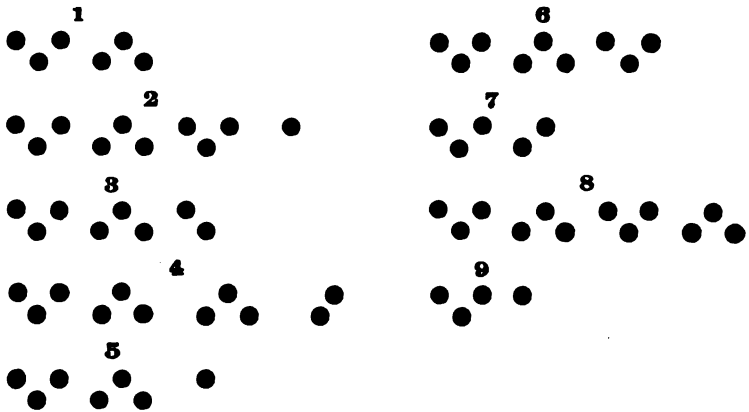
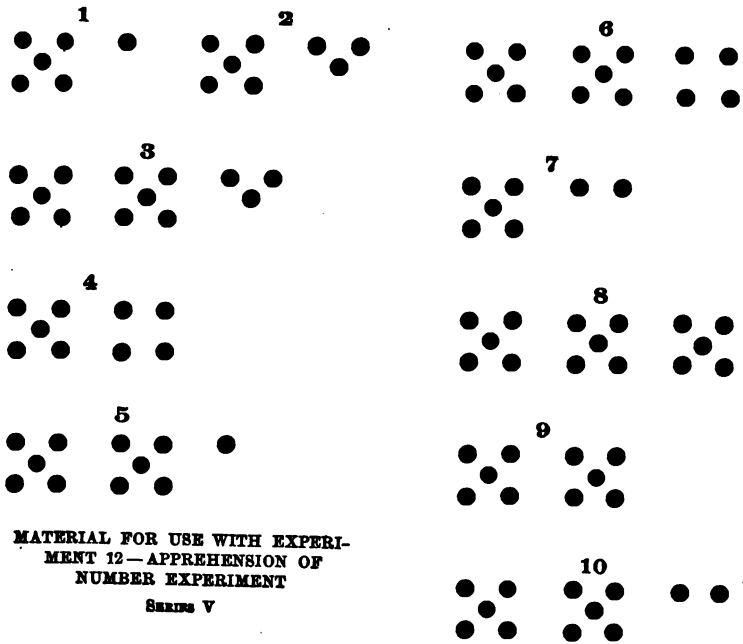
SERIES III



MATERIAL FOR USE WITH EXPERIMENT 12—APPREHENSION OF NUMBER
EXPERIMENT

Series IV



MATERIAL FOR USE WITH EXPERIMENT 12—APPREHENSION OF NUMBER EXPERIMENT

SERIES V

MATERIAL FOR USE WITH EXPERIMENT 15

PART B, RECONSTRUCTION OF SENTENCES

Series I

No. of words	
6	an boy the apple greedy ate
7	dog his faithful the slowly followed master
8	wolves outran the swift pursuing horse the soon
9	footsteps of they soon the heard afterward sound many
10	quickly the as cat flew siezed locust the up it
12	clearing on as the side they fugitive other the entered the disappeared
14	and his closed secretary the himself office door the seated of desk the at
16	watch the train at would his late traveler twenty the knew minutes and be glanced that

Series II

No. of words	
6	hungry bone the gnawed dog his
7	ran the ditch horse the into frightened
8	very prize the hard Mary and won studied
9	some said the steam boy saw he that yachts
10	and slowly the channel ship thru the narrow long sailed
12	every the approached herd cautiously it side hunters the and on surrounded
14	the fence-tops all had snow when day the drifts up the to were fallen
16	shed the further their departed tools in workmen disturbance homes placed the without and to their

EXPERIMENT 15 — KEY TO SENTENCE ARRANGEMENT

Series I	*Time (including writing)*
The greedy boy ate an apple	14
The faithful dog followed his master slowly	22
The swift horse soon outran the pursuing wolves	29
Soon afterward they heard the sound of many footsteps	33
As the locust flew up the cat quickly seized it	39[1]
As they entered the clearing the fugitive disappeared on the other side	47
The secretary closed the door of the office and seated himself at his desk	56
The traveler glanced at his watch and knew that the train would be twenty minutes late	66
Series II	
The hungry dog gnawed his bone	16
The frightened horse ran into the ditch	15
Mary studied very hard and won the prize	20
The boy said that he saw some steam yachts	30
The ship sailed thru the long and narrow channel.	38.5
The hunters approached the herd and cautiously surrounded it on every side	51.2
When the snow had fallen all day the drifts were up to the fence-tops	54.25
The workmen placed their tools in the shed and departed to their homes without further disturbance	64.8

[1] Estimated.

STIMULI FOR USE WITH EXPERIMENT 16

Opposites Test

Stimulus List No. 1	*Stimulus List No. 2*
1. intelligent	1. to respect .....
2. however	2. to hold .....
3. enthusiastic	3. exciting .....
4. traitor	4. simple .....
5. intricate	5. deceitful .....
6. sublime	6. permanent .....
7. petty	7. to degrade .....
8. languor	8. level .....
9. disdain	9. suspicious .....
10. thorough	10. pride .....
11. vacillating	11. despondent .....
12. fastidious	12. venturesome .....
13. important	13. silly .....
14. spendthrift	14. busy .....
15. motion	15. preserve .....
16. dextrous	16. abet .....
17. serious	17. abeyance .....
18. gentle	18. abnegation .....
19. unless	19. absolve .....
20. although	20. alternative .....
21. prohibit	21. captious .....
22. uncouth	22. equivocal .....
23. conceal	23. fame .....
24. precise	24. hazard.....
25. rigid	25. hypocrisy.....
26. suave	26. imminent .....
27. proficient.....	27. inherent .....
28. belief	28. pique .....
29. cruel	29. satisfy .....
30. result	30. terse .....

RESPONSE LIST FOR EXPERIMENT 16

Opposites Test

Response List No. 1	*Response List No. 2*
1. stupid	1. despise
2. accordingly (hence) [1]	2. to release
3. indifferent	3. soothing
4. patriot	4. complex
5. simple	5. frank, truthful
6. commonplace	6. temporary
7. noble	7. to ennoble
8. energy, vigor	8. tilted
9. respect	9. trustful
10. superficial	10. humility
11. constant	11. cheerful
12. negligent, slip-shod	12. cautious
13. insignificant	13. sensible
14. miser	14. idle
15. rest	15. destroy
16. clumsy	16. frustrate, impede, hinder
17. frivolous	17. enforcement, operation
18. rough	18. claim, demand
19. if	19. condemn
20. because	20. compulsion, necessity
21. permit	21. fair
22. cultured, polished	22. plain, unambiguous
23. reveal	23. oblivion
24. vague, careless	24. certainty
25. pliable	25. sincerity
26. brusque	26. improbable, contingent
27. unskilled	27. incidental, unconnected
28. doubt	28. complacency
29. sympathetic	29. disappoint
30. cause	30. diffuse

[1] Synonyms may be allowed. Do not use the prefix *un*.

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